[redacted]

[redacted] Copy 12
RM SL57C12

[redacted]

RESEARCH MEMORANDUM

for

U. S. Army Ordnance

WIND-TUNNEL INVESTIGATION OF THE EFFECT OF SPIN ON THE AERODYNAMIC CHARACTERISTICS OF A 60-MILLIMETER T-24 MORTAR SHELL WITH SEVERAL TAIL-FIN CONFIGURATIONS

By William B. Kemp, Jr., and William C. Hayes, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

[redacted]

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
MAR 21 1957

[redacted]

[redacted]

 [redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for

U. S. Army Ordnance

WIND-TUNNEL INVESTIGATION OF THE EFFECT OF SPIN ON THE AERODYNAMIC CHARACTERISTICS OF A 60-MILLIMETER T-24 MORTAR SHELL WITH SEVERAL TAIL-FIN CONFIGURATIONS

By William B. Kemp, Jr., and William C. Hayes, Jr.

SUMMARY

An investigation has been made in the Langley high-speed 7- by 10-foot tunnel to determine the effect of spin on the aerodynamic characteristics of the Army Ordnance Corps 60-millimeter T-24 mortar shell fitted with several different tail-fin configurations. Tests were made at airspeeds of 400 and 600 feet per second, at speeds of rotation from 0 to 5,000 rpm, and through the angle-of-attack range from -2° to 20°.

The results showed that under all test conditions the models were statically stable and that the yawing moment (primarily Magnus effect) increased with speed of rotation at the higher angles of attack. Tests with the model restrained in each of six positions about the longitudinal axis indicated that yawing moments, in some cases as large as those produced by a speed of rotation of 3,000 rpm, could arise presumably because of an unsymmetrical wake produced by the arming-pin slots in the model nose.

INTRODUCTION

At the request of the Picatinny Arsenal, Army Ordnance Corps, a series of tests were made in the Langley high-speed 7- by 10-foot tunnel to determine the effect of spin on the aerodynamic characteristics of the 60-mm T-24 mortar shell with various tail-fin configurations. Although the 60-mm T-24 mortar shell is fin stabilized, it may experience some spin about the longitudinal axis because of tail-fin misalinement

[redacted]

or unstable roll damping of the tail fins at large angles of attack. The Magnus moment arising from spin at high angles of attack may combine with gyroscopic moments to cause a precessional or whirling motion as discussed in reference 1. The resulting high drag would then cause the mortar shell to fall short of its expected range.

In order to evaluate the effect of the aerodynamic (Magnus) forces associated with the combination of spin and high angle of attack on the stability of the shell, this investigation included forced-spin and free-spin tests as well as tests with the model restrained in spin. The data presented in this paper were obtained from full-scale models at airspeeds of 400 and 600 feet per second through an angle-of-attack range from -2° to 20° at speeds of rotation from 0 to 5,000 rpm.

COEFFICIENTS AND SYMBOLS

The data presented herein are in the form of standard NACA coefficients of forces and moments which are referred to the axis system shown in figure 1 in which the X-axis is coincident with the X body axis and the Y- and Z-axes do not spin with the model. The origin is at the assumed center of gravity of each model configuration as indicated in figure 2. The positive directions of the forces, moments, and angles are also shown in figure 1. The coefficients and symbols are defined as follows:

C_N	normal-force coefficient, F_Z/qS
C_m	pitching-moment coefficient, M_Y/qSd
C_Y	lateral-force coefficient, F_Y/qS
C_n	yawing-moment coefficient, M_Z/qSd
F_Z	normal force, lb
M_Y	pitching moment, ft-lb
F_Y	side force, lb
M_Z	yawing moment, ft-lb
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
ρ	mass density of air, slugs/cu ft
V	free-stream velocity, ft/sec

S maximum cross-sectional area, sq ft

d maximum diameter of model, ft

α angle of attack, deg

ψ angle of yaw, deg

ϕ roll angle, deg

θ angle between z-axis and projection of wind on YZ-plane, $\tan^{-1} \frac{\psi}{\alpha}$, deg

n model speed of rotation, positive when in clockwise direction as viewed from rear, rpm

R spin rate, $\frac{1}{57.3} \frac{\partial \phi}{\partial t} \frac{d}{V}$, radians/caliber

MODEL AND APPARATUS

The full-scale model of the 60-mm T-24 mortar shell used in this investigation consisted of a magnesium-alloy body shape, a steel tail boom, and four detachable aluminum tail-fin configurations. The 0° and 4° fin configurations and the "half-barrel" shroud configuration were aluminum extrusions. The 4° fin configuration was formed by bending each fin of the 0° fin configuration approximately 4° along the bend line indicated in figure 2. The "regular" shroud configuration was of die-cast aluminum. Detailed drawings and photographs of the test configurations are presented as figures 2 and 3, respectively.

The model was mounted on the sting-support system in the Langley high-speed 7- by 10-foot tunnel and could be traversed through the angle-of-attack range by remote control. Forces were measured by electrical strain-gage balances which were an integral part of the model sting mount. Detailed balance calibrations which included interaction equations were supplied by Picatinny Arsenal. Further calibrations were made at the time of the tests only to determine the sensitivity constants of the read-out equipment used. The model was driven in rotation about the axis of symmetry by a water-cooled, variable-frequency electric motor mounted in the sting. The model was connected to the motor by a small drive shaft which extended from the model nose through the center of the model-sting mount to the motor drive shaft. The speed of rotation of the model was measured by a stroboscopic-type indicator connected to the tachometer within the model. A schematic drawing of the apparatus is presented as figure 4.

TESTS AND CORRECTIONS

The models were tested through an angle-of-attack range from -2° to 20°, a speed-of-rotation range from 0 to 5,000 revolutions per minute, and at airspeeds of 400 and 600 feet per second. Reynolds numbers corresponding to the test airspeeds were approximately 475,000 and 620,000, respectively, based on the maximum diameter of the model.

In the first series of tests (data presented in table I for forced-spin tests), the models were forced to rotate in a clockwise direction, when viewed from the rear, at the desired rate through the speed-of-rotation range; whereas, in the second series of tests (data presented in table II for free-spin tests), the model was allowed to rotate freely and was driven only by the action of the air on the model. In addition, a third series of tests (data presented in table III for zero-spin tests) was made with the models locked in each of six positions oriented at 60° intervals about the axis of symmetry.

Because of the stiffness of the balance in the pitch direction, no corrections were applied to the angle of attack to account for balance deflection under load; however, since the balance was extremely flexible in the yaw direction, the yaw angle actually existing during the tests varied with the aerodynamic side force and yawing moment. The value of yaw angle was calculated for each data point, using the measured side force and yawing moment together with results of a deflection calibration of the balance under static load.

RESULTS AND DISCUSSION

Presentation of Results

The data obtained in this investigation are presented in table I (forced-spin tests), table II (free-spin tests), and table III (zero-spin tests). Selected parts of the data are plotted for illustrative purposes in the figures 5 to 9.

Figures 5 to 8 show the variation of pitching-moment and yawing-moment coefficients with angle of attack for typical forced-spin tests. Figure 9 shows the variation of yawing-moment coefficient with angle of attack for one test configuration restrained in each of six equally spaced positions about the model longitudinal axis.

The values of C_Y and C_n presented herein are influenced by the existence of the yaw angle arising from deflection of the strain-gage balance. It is possible to obtain equivalent aerodynamic data for zero

yaw angle by rotation of the reference axis system about the X-axis through an angle $\theta = \tan^{-1} \frac{\psi}{\alpha}$ so that the relative wind lies in the rotated XZ-plane. The following expressions in which the primed values refer to the rotated axis system may then be derived:

$$
\begin{aligned}
\psi' &= 0 \\
\alpha' &= \alpha/\cos\theta \\
C_N' &= C_N \cos\theta + C_Y \sin\theta \\
C_m' &= C_m \cos\theta + C_n \sin\theta \\
C_Y' &= C_Y \cos\theta - C_N \sin\theta \\
C_n' &= C_n \cos\theta - C_m \sin\theta
\end{aligned}
$$

As an example, the data from forced-spin tests of the 0° fin configuration at a speed of rotation of 5,000 rpm and an 18° angle of attack have been converted to zero yaw angle with the following results:

$$
\begin{aligned}
& & \theta &= -4.19^{\circ} \\
\psi &= -1.32^{\circ} & \psi' &= 0 \\
\alpha &= 18.00^{\circ} & \alpha' &= 18.05^{\circ} \\
C_N &= 1.3066 & C_N' &= 1.3326 \\
C_m &= -1.5450 & C_m' &= -1.5843 \\
C_Y &= -0.4033 & C_Y' &= -0.3066 \\
C_n &= 0.5928 & C_n' &= 0.4782
\end{aligned}
$$

From these values it is seen that the yaw angle arising from balance deflection caused decreases in the normal force and pitching moment of less than 2.5 percent but caused the side force and yawing moment to be high by 31 percent and 24 percent, respectively, for the particular data point considered. These results are probably typical of the effect of balance deflection on all of the data at angles of attack high enough to produce significant lateral force and moment.

Forced-Spin Tests

Figure 5 presents the effect of model speed of rotation on the variation of pitching-moment coefficient with angle of attack for the regular shroud configuration. The results indicate that the model was statically stable, and the effect of increasing speed of rotation was to cause small increases in stability at high angles of attack. Since this trend was exhibited by all configurations, a typical speed of rotation (2,000 rpm) was chosen at which to demonstrate the effect of tail-fin configuration on the variation of pitching-moment coefficient with angle of attack (fig. 6). It may be seen that the rate of change of pitching-moment coefficient with angle of attack C_{m_α} became much more

negative for the unshrouded fins than for either shrouded fins at angles of attack above approximately 6°. The aerodynamic (predominantly Magnus) moment arising from the combined spin and angle of attack of the model is presented without allowance for sting deflection in figure 7 as variations of yawing-moment coefficient with angle of attack. There is a notable increase in yawing-moment coefficient with increase in speed of rotation above an angle of attack of 9° for all configurations.

Figure 8 presents the effect of the addition of the obturator ring to the 4° fin configuration on the variation of yawing-moment coefficient with angle of attack. The addition of the obturator ring generally increased the yawing moment above an angle of attack of 10° at the higher speeds of rotation.

Free-Spin Tests

The results of tests made with the model free to rotate about the longitudinal axis are presented in table II. Except for the 4° fin configuration which was designed to rotate under the influence of the air on the tail fins, none of the models rotated rapidly enough to experience large Magnus effects. In most cases the models rolled only slightly from side to side at certain angles of attack. Experience in other wind-tunnel tests (ref. 1, for example) has indicated that absence of spin instability at angles of attack less than 20° does not necessarily indicate lack of spin instability at higher angles of attack.

Zero-Spin Tests

The lateral forces and moments experienced by a symmetrical body with no spin and alined in a symmetrical flow should be zero. Any deviations from zero are probably due to model asymmetry or the formation of an asymmetrical wake. Figure 9 shows the variation of yawing-moment coefficient with angle of attack for the regular shroud configuration restrained in each of six positions about the longitudinal axis.

The yawing moments measured at high angles of attack were in some cases as large as those produced by speeds of rotation of over 3,000 rpm. The variation of yawing moment with roll angle appears to be cyclic with two cycles per revolution. The only physical characteristic of the model which seems capable of producing such a variation is the existence of the arming-pin grooves in the nose. These grooves are illustrated in figure 10. Flow through these grooves at high angles of attack probably produced an unsymmetrical wake which varied with roll angle. It may be expected that the high yawing moments could be essentially eliminated by use of an axially symmetric nose configuration.

[redacted]

CONCLUSIONS

The results of a wind-tunnel investigation to determine the effect of spin on the 60-mm T-24 mortar shell indicate the following conclusions:

1. In all cases the model is longitudinally statically stable, that is, the pitching moment tends to restore the longitudinal axis of the model to the flight path.

2. Within the test angle-of-attack range (-2° to 20°) the model did not experience a high spin rate when fitted with any of the tail-fin configurations except with the 4° fin configuration.

3. Yawing moments as large as those arising from spin rates up to 3,000 revolutions per minute may be encountered with no spin and are probably caused by air flow through the arming-pin grooves in the model nose.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 26, 1957.

William B. Kemp Jr.
William B. Kemp, Jr.
Supervisory Aeronautical Research Engineer

William C. Hayes Jr
William C. Hayes, Jr.
Aeronautical Research Engineer

Approved: Thomas A. Harris
Thomas A. Harris
Chief of Stability Research Division

ccb

REFERENCE

1. Bird, John D., and Lichtenstein, Jacob H.: An Investigation of a Source of Short-Round Behavior of Mortar Shells. NACA RM L56G20a, 1956.

[redacted]

TABLE I.- FORCED-SPIN TESTS

(a) 0° fin configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
n = 1,150 rpm; R = 0.0593						n = 1,150 rpm; R = 0.0395					
-2.00	-.07	-.0448	.0276	-.0182	.0241	-2.00	-.12	-.0463	.0230	-.0135	.0074
.00	-.05	.0120	.0022	-.0110	.0038	.00	-.16	.0127	-.0013	-.0192	.0153
1.00	-.06	.0787	-.0673	-.0159	.0139	1.00	-.14	.0719	-.0523	-.0178	.0159
2.00	-.07	.1138	-.0930	-.0189	.0182	2.00	-.18	.1193	-.0912	-.0236	.0254
3.00	-.08	.1348	-.0914	-.0220	.0236	3.00	-.18	.1634	-.1254	-.0235	.0251
4.00	-.09	.2031	-.1709	-.0233	.0239	4.00	-.19	.1952	-.1464	-.0265	.0305
6.00	-.11	.2743	-.2313	-.0294	.0338	6.00	-.22	.3178	-.2779	-.0312	.0392
9.00	-.13	.4813	-.4877	-.0375	.0452	9.00	-.30	.5058	-.5040	-.0425	.0555
14.00	-.23	.8306	-.9422	-.0631	.0754	14.00	-.49	.9063	-1.0214	-.0691	.0896
20.00	-.56	1.4155	-1.7681	-.1787	.2873						
n = 2,000 rpm; R = 0.1030						n = 2,000 rpm; R = 0.0687					
-2.00	-.05	-.0779	.0806	-.0116	.0063	-2.00	-.10	-.0465	.0234	-.0101	.0028
.00	-.07	.0043	.0208	-.0164	.0148	.00	-.14	.0253	-.0185	-.0164	.0125
1.00	-.07	.0526	-.0232	-.0194	.0184	1.00	-.14	.0751	-.0567	-.0190	.0182
2.00	-.07	.0792	-.0214	-.0200	.0185	2.00	-.17	.1065	-.0735	-.0230	.0237
3.00	-.11	.1481	-.1016	-.0304	.0356	3.00	-.20	.1574	-.1173	-.0254	.0253
4.00	-.12	.1770	-.1186	-.0328	.0386	4.00	-.23	.1924	-.1428	-.0302	.0341
6.00	-.13	.2879	-.2338	-.0378	.0435	6.00	-.29	.3183	-.2789	-.0411	.0534
9.00	-.19	.4968	-.4856	-.0516	.0540	9.00	-.37	.5129	-.5108	-.0502	.0589
14.00	-.35	.8766	-.9828	-.0942	.1026	14.00	-.66	.9081	-1.0179	-.0904	.1041
20.00	-.81	1.4409	-1.7947	-.2619	.4271						
n = 3,400 rpm; R = 0.1752						n = 3,400 rpm; R = 0.1168					
-2.00	-.03	-.0604	.0644	-.0065	.0023	-2.00	-.03	-.0766	.0693	-.0029	-.0054
.00	-.06	.0236	-.0060	-.0160	.0142	.00	-.12	.0127	-.0048	-.0142	.0108
1.00	-.08	.0590	-.0320	-.0204	.0208	1.00	-.13	.0504	-.0301	-.0166	.0150
2.00	-.10	.1268	-.1028	-.0267	.0302	2.00	-.18	.1044	-.0782	-.0236	.0255
3.00	-.12	.1756	-.1476	-.0313	.0332	3.00	-.23	.1621	-.1353	-.0312	.0377
4.00	-.14	.2188	-.1923	-.0376	.0415	4.00	-.25	.2066	-.1701	-.0349	.0417
6.00	-.16	.3007	-.2905	-.0433	.0492	6.00	-.32	.3268	-.2987	-.0447	.0530
9.00	-.28	.5258	-.5274	-.0706	.0631	9.00	-.45	.5282	-.5367	-.0596	.0610
14.00	-.49	.9331	-1.0492	-.1224	.0960	14.00	-.91	.9087	-1.0205	-.1219	.1318
n = 5,000 rpm; R = 0.2576						n = 5,000 rpm; R = 0.1717					
-2.00	.00	-.0821	.1489	.0012	-.0067	-2.00	-.03	.1243	-.2859	-.0031	-.0040
.00	-.05	.0102	.0589	-.0114	.0053	.00	-.12	.0185	.0140	-.0142	.0093
1.00	-.08	.0655	.0050	-.0182	.0118	1.00	-.18	.0625	-.0165	-.0225	.0200
2.00	-.10	.1220	-.0582	-.0239	.0161	2.00	-.20	.1138	-.0647	-.0258	.0244
3.00	-.12	.1850	-.1303	-.0296	.0204	3.00	-.23	.1738	-.1173	-.0283	.0254
4.00	-.15	.2353	-.1851	-.0360	.0240	4.00	-.30	.2127	-.1484	-.0397	.0413
6.00	-.22	.3265	-.2657	-.0570	.0517	6.00	-.41	.3271	-.2693	-.0531	.0540
9.00	-.34	.5426	-.5064	-.0794	.0438	9.00	-.65	.5311	-.4963	-.0824	.0751
14.00	-.71	.9272	-.9738	-.1788	.1625	14.00	-1.30	.9062	-.9660	-.1705	.1758
18.00	-1.32	1.3066	-1.5450	-.4033	.5928						

[redacted]

[redacted]

[redacted]

TABLE I.- FORCED-SPIN TESTS - Continued

(b) 4° fin configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
n = 1,150 rpm; R = 0.0593						n = 1,200 rpm; R = 0.0412					
-2.00	-.06	-.1093	.0950	-.0172	.0199	-2.00	-.10	-.1170	.1119	-.0111	.0070
.00	-.06	-.0418	.0540	-.0177	.0199	.00	-.13	-.0266	.0417	-.0154	.0124
1.00	-.08	.0165	.0033	-.0236	.0306	1.00	-.13	.0176	.0136	-.0165	.0149
2.00	-.10	.0499	-.0131	-.0266	.0339	2.00	-.14	.0625	-.0190	-.0182	.0178
3.00	-.10	.0906	-.0470	-.0301	.0391	3.00	-.15	.1104	-.0559	-.0210	.0229
4.00	-.11	.1499	-.1065	-.0324	.0445	4.00	-.16	.1623	-.1056	-.0224	.0269
6.00	-.13	.2502	-.2005	-.0395	.0548	6.00	-.19	.2758	-.2188	-.0278	.0359
9.00	-.15	.4461	-.4347	-.0437	.0578	9.00	-.26	.4741	-.4570	-.0375	.0488
14.00	-.27	.8399	-.9515	-.0748	.0945	14.00	-.47	.8659	-.9528	-.0688	.0921
20.00	-.62	1.3676	-1.6897	-.2054	.3453						
n = 2,000 rpm; R = 0.1031						n = 2,000 rpm; R = 0.0687					
-2.00	-.01	-.0535	.0249	-.0013	-.0130	-2.00	-.08	-.1092	.1044	-.0100	.0048
.00	-.03	-.0008	.0194	-.0071	-.0039	.00	-.10	-.0158	.0343	-.0128	.0097
1.00	-.04	.0261	.0122	-.0082	-.0019	1.00	-.13	.0359	-.0077	-.0166	.0143
2.00	-.06	.0920	-.0566	-.0130	.0054	2.00	-.14	.0773	-.0315	-.0189	.0196
3.00	-.08	.1444	-.0993	-.0195	.0141	3.00	-.16	.1171	-.0608	-.0215	.0221
4.00	-.09	.2041	-.1596	-.0237	.0198	4.00	-.19	.1727	-.1156	-.0262	.0306
6.00	-.11	.2992	-.2539	-.0267	.0230	6.00	-.24	.2840	-.2253	-.0343	.0448
9.00	-.17	.5028	-.4993	-.0402	.0320	9.00	-.31	.4807	-.4575	-.0433	.0521
14.00	-.30	.8903	-1.0005	-.0775	.0709	14.00	-.62	.8802	-.9644	-.0865	.1048
20.00	-.76	1.4833	-1.8513	-.2466	.4003						
n = 3,200 rpm; R = 0.1649						n = 3,200 rpm; R = 0.1099					
-2.00	.01	-.0078	-.0083	.0118	-.0373	-2.00	-.03	.1575	-.3879	-.0015	-.0103
.00	-.03	.0186	-.0078	-.0043	-.0137	.00	-.09	-.0077	.0341	-.0094	.0000
1.00	-.05	.0767	-.0583	-.0101	-.0030	1.00	-.11	.0376	.0010	-.0120	.0037
2.00	-.05	.1437	-.1363	-.0108	-.0051	2.00	-.15	.0890	-.0407	-.0190	.0158
3.00	-.09	.1709	-.1442	-.0186	.0058	3.00	-.19	.1284	-.0657	-.0249	.0234
4.00	-.10	.2129	-.1876	-.0228	.0102	4.00	-.22	.1780	-.1122	-.0281	.0276
6.00	-.14	.3082	-.2827	-.0324	.0212	6.00	-.29	.2939	-.2358	-.0393	.0449
9.00	-.22	.5267	-.5266	-.0537	.0424	9.00	-.43	.4899	-.4565	-.0566	.0591
14.00	-.44	.9013	-1.0035	-.1139	.1067	14.00	-.86	.9120	-.9917	-.1175	.1332
20.00	-1.09	1.4965	-1.8871	-.3506	.5631						
n = 5,000 rpm; R = 0.2576						n = 5,000 rpm; R = 0.1717					
-2.00	-.01	-.0849	.1065	-.0039	-.0010	-2.00	-.02	-.1023	.1246	-.0019	-.0062
.00	-.06	.0235	-.0069	-.0131	.0046	.00	-.10	-.0034	.0395	-.0114	.0053
1.00	-.08	.0822	-.0587	-.0191	.0103	1.00	-.14	.0461	-.0031	-.0168	.0118
2.00	-.10	.1369	-.1197	-.0234	.0135	2.00	-.21	.0963	-.0506	-.0272	.0261
3.00	-.12	.2044	-.1987	-.0301	.0187	3.00	-.22	.1457	-.0932	-.0290	.0260
4.00	-.15	.2592	-.2600	-.0345	.0206	4.00	-.27	.1963	-.1449	-.0350	.0337
6.00	-.21	.3560	-.3578	-.0469	.0249	6.00	-.40	.3127	-.2656	-.0532	.0589
9.00	-.34	.5502	-.5615	-.0788	.0505	9.00	-.62	.5069	-.4767	-.0807	.0798
14.00	-.67	.9312	-1.0334	-.1700	.1527	14.00	-1.18	.8993	-.9719	-.1551	.1563
18.00	-1.19	1.3604	-1.6507	-.3527	.4893						

[redacted]

[redacted]

TABLE I.- FORCED-SPIN TESTS - Continued

(c) Regular shroud configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
n = 1,200 rpm; R = 0.0618						n = 1,200 rpm; R = 0.0412					
-2.00	-.11	-.1426	.1281	-.0350	.0598	-2.00	-.07	-.0904	.0891	-.0071	.0003
.00	-.11	-.0546	.0406	-.0339	.0520	.00	-.07	-.0062	.0217	-.0073	-.0013
1.00	-.11	-.0090	.0019	-.0326	.0494	1.00	-.11	.0393	-.0209	-.0119	.0083
2.00	-.12	.0168	.0005	-.0361	.0548	2.00	-.13	.0853	-.0641	-.0151	.0123
3.00	-.13	.0715	-.0670	-.0362	.0509	3.00	-.13	.1237	-.0887	-.0165	.0139
4.00	-.14	.1112	-.0968	-.0410	.0576	4.00	-.15	.1750	-.1362	-.0194	.0194
6.00	-.15	.1902	-.1557	-.0439	.0609	6.00	-.17	.2666	-.2035	-.0224	.0254
9.00	-.20	.3306	-.2546	-.0598	.0871	9.00	-.26	.4013	-.2877	-.0358	.0453
14.00	-.31	.6000	-.4427	-.0923	.1400	14.00	-.48	.6634	-.4381	-.0679	.0942
20.00	-.67	.9702	-.7211	-.2241	.4125						
n = 2,000 rpm; R = 0.1031						n = 2,000 rpm; R = 0.0687					
-2.00	-.10	-.1159	.1181	-.0301	.0513	-2.00	-.06	-.0816	.0760	-.0075	.0044
.00	-.11	-.0403	.0491	-.0315	.0471	.00	-.10	.0098	-.0062	-.0126	.0091
1.00	-.11	-.0134	.0385	-.0350	.0525	1.00	-.12	.0493	-.0396	-.0143	.0123
2.00	-.13	.0350	-.0196	-.0375	.0534	2.00	-.14	.0940	-.0736	-.0169	.0157
3.00	-.13	.0747	-.0494	-.0387	.0530	3.00	-.16	.1333	-.1032	-.0204	.0193
4.00	-.15	.1083	-.0701	-.0399	.0513	4.00	-.17	.1748	-.1324	-.0210	.0195
6.00	-.18	.2066	-.1583	-.0489	.0627	6.00	-.22	.2704	-.2096	-.0285	.0314
9.00	-.24	.3501	-.2774	-.0657	.0833	9.00	-.34	.4149	-.3087	-.0450	.0535
14.00	-.42	.6187	-.4569	-.1249	.1870	14.00	-.64	.6767	-.4516	-.0891	.1193
20.00	-.85	1.0040	-.7731	-.2830	.5086						
n = 3,400 rpm; R = 0.1752						n = 3,400 rpm; R = 0.1168					
-2.00	-.03	-.1259	.1558	-.0086	.0115	-2.00	-.01	-.0669	.0578	.0011	-.0102
.00	-.06	-.0564	.0958	-.0141	.0136	.00	-.06	.0153	-.0105	-.0063	-.0015
1.00	-.07	-.0025	.0367	-.0173	.0124	1.00	-.08	.0638	-.0541	-.0087	-.0002
2.00	-.09	.0439	-.0032	-.0210	.0142	2.00	-.12	.1026	-.0793	-.0129	.0045
3.00	-.11	.0788	-.0335	-.0247	.0160	3.00	-.15	.1388	-.1043	-.0158	.0070
4.00	-.14	.1126	-.0547	-.0326	.0254	4.00	-.17	.1810	-.1382	-.0202	.0138
6.00	-.18	.2190	-.1630	-.0424	.0325	6.00	-.28	.2773	-.2168	-.0353	.0350
9.00	-.29	.3682	-.2833	-.0747	.0798	9.00	-.45	.4260	-.3230	-.0574	.0583
14.00	-.55	.6385	-.4732	-.1615	.2323	14.00	-.60	.6983	-.4909	-.0858	.1228
20.00	-1.16	1.0559	-.8450	-.3818	.6799						
n = 5,000 rpm; R = 0.2576						n = 5,000 rpm; R = 0.1717					
-2.00	-.03	-.1285	.1370	-.0076	.0069	-2.00	-.01	-.0681	.0671	-.0009	-.0053
.00	-.04	-.0418	.0659	-.0091	-.0037	.00	-.06	.0207	-.0115	-.0053	-.0069
1.00	-.09	.0123	.0065	-.0206	.0104	1.00	-.09	.0597	-.0370	-.0086	-.0055
2.00	-.10	.0518	-.0159	-.0215	.0019	2.00	-.13	.1112	-.0816	-.0128	-.0038
3.00	-.12	.0805	-.0371	-.0252	.0025	3.00	-.16	.1811	-.1944	-.0163	-.0019
4.00	-.16	.1137	-.0499	-.0314	.0052	4.00	-.22	.1930	-.1422	-.0222	.0029
6.00	-.21	.2065	-.1233	-.0421	.0042	6.00	-.34	.2840	-.2169	-.0386	.0233
9.00	-.37	.3834	-.2935	-.0868	.0638	9.00	-.58	.4341	-.3293	-.0686	.0556
14.00	-.75	.6879	-.5502	-.2124	.2881	14.00	-1.20	.7227	-.5319	-.1618	.2003
18.00	-1.31	.9351	-.7860	-.4164	.7054						

[redacted]

[redacted]

TABLE I.- FORCED-SPIN TESTS - Continued

(d) Half-barrel shroud configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
n = 1,200 rpm; R = 0.0618						n = 1,300 rpm; R = 0.0447					
-2.00	-.05	-.1205	.1552	-.0129	.0119	-2.00	-.07	-.0854	.0911	-.0097	.0094
.00	-.06	-.0397	.0832	-.0152	.0148	.00	-.09	.0095	-.0047	-.0114	.0100
1.00	-.06	.0155	.0109	-.0158	.0152	1.00	-.10	.0566	-.0502	-.0126	.0114
2.00	-.07	.0559	-.0251	-.0164	.0155	2.00	-.11	.0975	-.0867	-.0135	.0114
3.00	-.08	.0891	-.0433	-.0181	.0168	3.00	-.14	.1455	-.1374	-.0172	.0149
4.00	-.09	.1364	-.0895	-.0207	.0162	4.00	-.16	.1992	-.1926	-.0196	.0161
6.00	-.11	.2429	-.1990	-.0261	.0191	6.00	-.16	.2929	-.2790	-.0192	.0136
9.00	-.14	.4042	-.3354	-.0327	.0226	9.00	-.25	.4539	-.4028	-.0297	.0247
14.00	-.25	.6758	-.5409	-.0700	.0930	14.00	-.55	.7427	-.6276	-.0828	.1284
20.00	-.65	1.1075	-.9668	-.2383	.4733						
n = 2,000 rpm; R = 0.1031						n = 2,000 rpm; R = 0.0687					
-2.00	-.02	-.0965	.1278	-.0041	-.0069	-2.00	-.02	-.0821	.0824	-.0025	-.0042
.00	-.05	-.0138	.0454	-.0114	.0001	.00	-.08	.0096	-.0049	-.0085	.0037
1.00	-.07	.0258	.0178	-.0155	.0046	1.00	-.10	.0601	-.0550	-.0121	.0103
2.00	-.08	.0740	-.0370	-.0162	.0026	2.00	-.13	.1020	-.0968	-.0151	.0128
3.00	-.09	.1075	-.0558	-.0193	.0036	3.00	-.14	.1522	-.1431	-.0176	.0140
4.00	-.09	.1548	-.1020	-.0182	-.0038	4.00	-.17	.1969	-.1852	-.0198	.0131
6.00	-.11	.2613	-.2114	-.0231	-.0014	6.00	-.23	.3065	-.2871	-.0259	.0171
9.00	-.17	.4177	-.3413	-.0342	.0009	9.00	-.31	.4488	-.3986	-.0360	.0248
14.00	-.38	.7091	-.5827	-.1052	.1376	14.00	-.65	.7523	-.6404	-.0942	.1299
20.00	-.86	1.1171	-.9886	-.3041	.5856						
n = 3,400 rpm; R = 0.1752						n = 3,400 rpm; R = 0.1168					
-2.00	-.01	-.1000	.1340	-.0053	.0144	-2.00	-.03	.1375	-.3523	-.0056	.0096
.00	-.05	-.0032	.0313	-.0151	.0224	.00	-.10	.0116	-.0037	-.0129	.0169
1.00	-.07	.0243	.0217	-.0182	.0247	1.00	-.13	.0595	-.0504	-.0175	.0206
2.00	-.08	.0870	-.0617	-.0219	.0265	2.00	-.16	.1140	-.1103	-.0226	.0280
3.00	-.10	.1329	-.0906	-.0245	.0233	3.00	-.18	.1552	-.1436	-.0228	.0221
4.00	-.12	.1734	-.1193	-.0283	.0236	4.00	-.23	.2060	-.1909	-.0278	.0242
6.00	-.17	.2747	-.2136	-.0430	.0369	6.00	-.31	.3042	-.2804	-.0371	.0290
9.00	-.26	.4351	-.3562	-.0612	.0436	9.00	-.49	.4569	-.4037	-.0596	.0496
14.00	-.58	.7398	-.6375	-.1721	.2559	14.00	-.97	.7587	-.6503	-.1400	.1973
20.00	-1.31	1.1854	-1.1171	-.4661	.9051						
n = 5,000 rpm; R = 0.2576						n = 5,000 rpm; R = 0.1717					
-2.00	-.04	-.0927	.1539	-.0160	.0362	-2.00	-.02	-.0757	.0850	-.0039	.0085
.00	-.08	-.0008	.0582	-.0226	.0311	.00	-.09	.0131	.0091	-.0115	.0092
1.00	-.10	.0412	.0198	-.0270	.0320	1.00	-.14	.0582	-.0374	-.0170	.0163
2.00	-.11	.0951	-.0280	-.0273	.0230	2.00	-.19	.1060	-.0803	-.0235	.0202
3.00	-.14	.1374	-.0670	-.0342	.0260	3.00	-.23	.1506	-.1187	-.0258	.0162
4.00	-.15	.1786	-.0967	-.0351	.0175	4.00	-.25	.1952	-.1571	-.0258	.0076
6.00	-.23	.2879	-.2025	-.0496	.0228	6.00	-.37	.2939	-.2475	-.0413	.0201
9.00	-.35	.4364	-.3204	-.0802	.0450	9.00	-.58	.4474	-.3690	-.0644	.0304
14.00	-.75	.7656	-.6516	-.2169	.2978	14.00	-1.23	.7593	-.6305	-.1742	.2289
18.00	-1.35	1.0610	-1.0191	-.4563	.8296						

[redacted]

TABLE I.- FORCED-SPIN TESTS - Concluded

(e) 4^{o} fin configuration with obturator ring at V = 400 ft/sec

α, deg	ψ, deg	C_N	C_m	C_Y	C_n
n = 1,150 rpm; R = 0.0593					
-2.00	-.06	-.0937	.0877	-.0157	.0148
.00	-.07	-.0201	.0465	-.0198	.0214
1.00	-.09	.0135	.0305	-.0245	.0300
2.00	-.08	.0663	-.0122	-.0239	.0280
3.00	-.11	.1084	-.0554	-.0304	.0407
4.00	-.11	.1497	-.0898	-.0316	.0415
6.00	-.12	.2387	-.1676	-.0358	.0457
9.00	-.16	.4650	-.4587	-.0480	.0627
14.00	-.27	.8397	-.9562	-.0759	.0933
20.00	-.63	1.3976	-1.7597	-.2060	.3368
n = 2,000 rpm; R = 0.1031					
-2.00	-.05	-.1067	.1058	-.0126	.0111
.00	-.08	-.0392	.0730	-.0234	.0281
1.00	-.09	.0009	.0479	-.0276	.0350
2.00	-.10	.0686	-.0306	-.0263	.0326
3.00	-.11	.1088	-.0561	-.0287	.0342
4.00	-.12	.1704	-.1262	-.0348	.0440
6.00	-.16	.2798	-.2402	-.0445	.0565
9.00	-.22	.4480	-.4361	-.0601	.0682
14.00	-.36	.8294	-.9362	-.0962	.1013
20.00	-.88	1.3693	-1.7291	-.2863	.4665
n = 3,400 rpm; R = 0.1752					
-2.00	-.02	-.0993	.1265	-.0044	.0032
.00	-.05	-.0216	.0565	-.0130	.0122
1.00	-.08	.0210	.0124	-.0209	.0233
2.00	-.10	.0663	-.0125	-.0299	.0378
3.00	-.13	.1219	-.0747	-.0343	.0398
4.00	-.15	.1722	-.1371	-.0435	.0520
6.00	-.18	.2699	-.2352	-.0481	.0463
9.00	-.27	.5004	-.5032	-.0676	.0534
14.00	-.60	.8521	-.9633	-.1586	.1664
20.00	-1.44	1.4319	-1.8482	-.4734	.7859
n = 5,000 rpm; R = 0.2576					
-2.00	-.02	-.1180	.1906	-.0054	.0076
.00	-.07	-.0256	.0921	-.0185	.0175
1.00	-.10	.0364	.0209	-.0259	.0245
2.00	-.13	.0856	-.0323	-.0333	.0326
3.00	-.14	.1413	-.0947	-.0347	.0284
4.00	-.17	.2175	-.1932	-.0434	.0352
6.00	-.25	.2963	-.2654	-.0607	.0509
9.00	-.37	.5021	-.4925	-.0875	.0558
14.00	-.77	.8965	-.9901	-.1993	.1913
18.00	-1.40	1.2963	-1.5963	-.4256	.6255

TABLE II.- FREE-SPIN TESTS

(a) 0° fin configuration

α, deg	ψ, deg	n, rpm	R	C_N	C_m	C_Y	C_n
V = 400 ft/sec							
-2.00	-.02	0000	.0000	-.1408	.1686	-.0003	-.0211
.00	-.02	0000	.0000	-.0690	.1208	.0011	-.0213
1.00	-.02	0000	.0000	.0683	.0842	.0005	-.0207
2.00	-.02	0000	.0000	.0120	.0818	.0007	-.0216
3.00	-.02	0000	.0000	.0517	.0490	-.0004	-.0196
4.00	-.02	0000	.0000	.1036	-.0009	-.0015	-.0177
6.00	-.01	0000	.0000	.2152	-.1192	.0048	-.0341
9.00	-.02	0000	.0000	.3854	-.3103	-.0034	-.0093
14.00	.00	-0118	-.0061	.7487	-.7909	-.0006	-.0017
20.00	.27	-0452	-.0233	1.2650	-1.4862	.1064	-.2322
V = 600 ft/sec							
-2.00	-.02	0000	.0000	-.1176	.1130	.0004	-.0095
.00	-.03	0000	.0000	-.0284	.0554	-.0005	-.0136
1.00	-.03	0000	.0000	.0128	.0315	-.0016	-.0118
2.00	-.04	0000	.0000	.0602	-.0012	-.0024	-.0114
3.00	-.04	0000	.0000	.1044	-.0292	-.0029	-.0101
4.00	-.04	0000	.0000	.1560	-.0749	-.0022	-.0120
6.00	-.04	0000	.0000	.2545	-.1676	-.0008	-.0197
9.00	-.05	0000	.0000	.4465	-.3751	.0038	-.0349
14.00	-.32	0000	.0000	.8137	-.8051	-.0541	.0944

(b) 4° fin configuration

α, deg	ψ, deg	n, rpm	R	C_N	C_m	C_Y	C_n
V = 400 ft/sec							
-2.00	-.02	1422	.0733	-.0889	.0889	-.0059	.0007
.00	-.04	1484	.0765	-.0076	.0294	-.0082	.0021
1.00	-.05	1522	.0784	.0464	-.0228	-.0101	.0033
2.00	-.05	1454	.0749	.0673	-.0212	-.0136	.0097
3.00	-.08	1418	.0731	.1350	-.1000	-.0184	.0172
4.00	-.08	1406	.0724	.1825	-.1431	-.0202	.0197
6.00	-.09	1370	.0706	.2908	-.2478	-.0221	.0170
9.00	-.13	1500	.0773	.5659	-.6681	-.0301	.0132
14.00	-.37	2510	.1293	.9953	-1.0151	-.0790	.0245
20.00	-1.24	3996	.2059	1.4739	-1.8656	-.3657	.5059
V = 600 ft/sec							
-2.00	-.04	2192	.0753	-.0961	.0669	-.0050	.0010
.00	-.07	2282	.0784	-.0080	.0090	-.0084	.0064
1.00	-.10	2276	.0782	.0445	-.0339	-.0114	.0085
2.00	-.12	2204	.0757	.0837	-.0543	-.0141	.0116
3.00	-.14	2172	.0746	.1311	-.0976	-.0177	.0149
4.00	-.15	2122	.0729	.1869	-.1486	-.0188	.0168
6.00	-.19	2028	.0697	.3040	-.2698	-.0234	.0200
9.00	-.29	2217	.0762	.5013	-.4991	-.0324	.0158
14.00	-.76	3100	.1065	.9871	-.9856	-.0837	.0323

[redacted]

TABLE II.- FREE-SPIN TESTS - Concluded

(c) Regular shroud configuration

α, deg	ψ, deg	n, rpm	R	C_N	C_m	C_Y	C_n
V = 400 ft/sec							
-2.00	-.06	0000	.0000	-.1183	.1446	-.0192	.0298
.00	-.08	0000	.0000	-.0468	.0966	-.0237	.0409
1.00	-.07	0000	.0000	-.0067	.0587	-.0219	.0379
2.00	-.06	0000	.0000	.0321	.0302	-.0199	.0359
3.00	-.06	0000	.0000	.0774	-.0081	-.0198	.0356
4.00	-.05	0000	.0000	.1176	-.0462	-.0174	.0308
6.00	-.05	0000	.0000	.2095	-.1324	-.0156	.0249
9.00	-.05	0000	.0000	.3544	-.2387	-.0153	.0238
14.00	-.01	-0118	-.0061	.5984	-.3608	-.0003	-.0168
20.00	-.70	0000	.0000	.9634	-.5840	-.2285	.3999
V = 600 ft/sec							
-2.00	-.08	-0146	-.0050	-.0873	.0842	-.0086	.0016
.00	-.07	-0338	-.0116	-.0069	.0230	-.0086	.0062
1.00	-.07	-0306	-.0105	.0354	-.0145	-.0090	.0095
2.00	-.08	-0256	-.0088	.0526	-.0106	-.0113	.0145
3.00	-.09	-0132	-.0045	.1071	-.0628	-.0124	.0165
4.00	-.10	-0062	-.0021	.1482	-.0910	-.0151	.0250
6.00	-.06	0000	.0000	.2612	-.1971	-.0144	.0365
9.00	-.12	0000	.0000	.3705	-.2426	-.0253	.0573
14.00	-.06	0000	.0000	.6220	-.3655	-.0081	.0090

(d) Half-barrel shroud configuration

α, deg	ψ, deg	n, rpm	R	C_N	C_m	C_Y	C_n
V = 400 ft/sec							
-2.00	-.05	0000	.0000	-.1173	.1588	-.0197	.0366
.00	-.07	0000	.0000	-.0277	.0593	-.0226	.0414
1.00	-.07	0000	.0000	.0202	.0051	-.0225	.0412
2.00	-.06	0000	.0000	.0720	-.0396	-.0212	.0399
3.00	-.07	0000	.0000	.1063	-.0669	-.0248	.0452
4.00	-.07	0000	.0000	.1407	-.0940	-.0230	.0410
6.00	-.06	0000	.0000	.2389	-.1831	-.0203	.0396
9.00	-.04	0000	.0000	.3931	-.3083	-.0176	.0366
14.00	-.06	0000	.0000	.6642	-.4976	-.0202	.0360
20.00	-.02	0000	.0000	1.0639	-.8505	-.0056	-.0008
V = 600 ft/sec							
-2.00	-.06	0000	.0000	-.1069	.1263	-.0074	.0063
.00	-.09	0000	.0000	-.0133	.0320	-.0124	.0145
1.00	-.08	0000	.0000	.0323	-.0077	-.0102	.0125
2.00	-.08	0000	.0000	.0814	-.0525	-.0101	.0116
3.00	-.08	0000	.0000	.1186	-.0839	-.0107	.0119
4.00	-.07	0000	.0000	.1705	-.1328	-.0106	.0129
6.00	-.11	0000	.0000	.2743	-.2269	-.0158	.0219
9.00	-.12	0000	.0000	.4161	-.3200	-.0184	.0270
14.00	-.06	0000	.0000	.7054	-.5328	-.0097	.0138

TABLE III.- ZERO-SPIN TESTS

(a) 0° configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
φ = 0°						φ = 0°					
-2.00	-.07	-.0424	.0081	-.0197	.0219	-2.00	-.13	-.0619	.0176	-.0151	.0121
.00	-.07	.0130	-.0067	-.0195	.0213	.00	-.11	.0182	-.0277	-.0139	.0114
1.00	-.07	.0676	-.0590	-.0194	.0224	1.00	-.11	.0489	-.0395	-.0139	.0111
2.00	-.08	.1008	-.0663	-.0230	.0275	2.00	-.11	.0886	-.0596	-.0146	.0140
3.00	-.08	.1427	-.1013	-.0206	.0215	3.00	-.13	.1330	-.0943	-.0161	.0150
4.00	-.08	.2048	-.1716	-.0204	.0239	4.00	-.11	.1994	-.1591	-.0147	.0156
6.00	-.07	.3030	-.2764	-.0214	.0310	6.00	-.11	.3102	-.2817	-.0151	.0196
9.00	-.02	.4854	-.4979	-.0046	.0045	9.00	.02	.5110	-.5324	.0036	-.0056
14.00	.25	.8935	-1.0493	.1001	-.2110	14.00	.63	.9020	-1.0447	.1211	-.2463
φ = 60°						φ = 60°					
-2.00	-.05	-.0688	.0520	-.0113	.0009	-2.00	-.12	-.0715	.0348	-.0121	.0032
.00	-.06	-.0267	.0559	-.0134	.0074	.00	-.12	-.0068	.0029	-.0131	.0081
1.00	-.05	.0151	.0213	-.0140	.0089	1.00	-.11	.0418	-.0258	-.0132	.0099
2.00	-.06	.0684	-.0215	-.0144	.0117	2.00	-.11	.0786	-.0461	-.0146	.0139
3.00	-.06	.1103	-.0563	-.0150	.0119	3.00	-.14	.1235	-.0852	-.0182	.0192
4.00	-.06	.1648	-.1084	-.0155	.0148	4.00	-.13	.1870	-.1500	-.0189	.0235
6.00	-.06	.2582	-.2146	-.0166	.0181	6.00	-.14	.2934	-.2591	-.0191	.0240
9.00	-.06	.4937	-.5104	-.0161	.0109	9.00	-.16	.5071	-.5404	-.0194	.0156
14.00	-.05	.8599	-1.0267	-.0022	-.0354	14.00	-.47	.9071	-1.0764	-.0682	.0906
20.00	-.24	1.4409	-1.8558	-.0652	.0590						
φ = 120°						φ = 120°					
-2.00	-.04	-.0677	.0429	-.0094	-.0018	-2.00	-.08	-.1007	.0756	-.0090	.0008
.00	-.05	-.0254	.0463	-.0117	.0034	.00	-.08	-.0132	.0118	-.0088	.0002
1.00	-.04	.0215	.0124	-.0091	-.0002	1.00	-.08	.0324	-.0129	-.0087	-.0002
2.00	-.05	.0620	-.0127	-.0114	.0054	2.00	-.08	.0702	-.0420	-.0085	.0028
3.00	-.05	.1245	-.0838	-.0108	.0034	3.00	-.09	.1165	-.0718	-.0100	.0037
4.00	-.05	.1598	-.1095	-.0107	.0032	4.00	-.09	.1714	-.1286	-.0100	.0035
6.00	-.05	.2720	-.2341	-.0119	.0026	6.00	-.11	.2879	-.2519	-.0130	.0056
9.00	-.08	.4654	-.4803	-.0133	-.0175	9.00	-.19	.5033	-.5328	-.0170	-.0143
14.00	-.24	.8850	-1.0644	-.0517	.0097	14.00	-.67	.9056	-1.0640	-.0682	.0058
20.00	-.62	1.4398	-1.8568	-.1790	.2363						
φ = 180°						φ = 180°					
-2.00	-.06	-.0688	.0526	-.0122	.0069	-2.00	-.07	-.0843	.0533	-.0073	-.0004
.00	-.06	-.0074	.0291	-.0121	.0063	.00	-.08	-.0021	.0079	-.0087	.0001
1.00	-.06	.0395	-.0050	-.0144	.0105	1.00	-.08	.0411	-.0214	-.0086	-.0002
2.00	-.06	.0670	-.0123	-.0132	.0080	2.00	-.09	.0840	-.0503	-.0100	.0039
3.00	-.06	.1213	-.0645	-.0149	.0118	3.00	-.08	.1244	-.0795	-.0096	.0046
4.00	-.05	.1756	-.1166	-.0130	.0088	4.00	-.08	.1769	-.1218	-.0097	.0058
6.00	-.05	.2735	-.2214	-.0122	.0093	6.00	-.07	.2987	-.2560	-.0089	.0075
9.00	.01	.4811	-.4855	.0022	-.0086	9.00	.04	.4980	-.5089	.0089	-.0181
14.00	.27	.8740	-1.0231	.1040	-.2118	14.00	.66	.9194	-1.0707	.1216	-.2384
20.00	.78	1.4100	-1.7701	.3127	-.6591						
φ = 240°						φ = 240°					
-2.00	-.03	-.0608	.0340	-.0062	-.0055	-2.00	-.08	-.0456	.0000	-.0088	.0008
.00	-.03	-.0126	.0287	-.0066	-.0031	.00	-.10	-.0011	-.0009	-.0119	.0078
1.00	-.04	.0284	-.0051	-.0083	.0020	1.00	-.10	.0410	-.0251	-.0121	.0096
2.00	-.04	.0674	-.0207	-.0099	.0056	2.00	-.09	.0797	-.0445	-.0112	.0113
3.00	-.04	.1289	-.0906	-.0099	.0067	3.00	-.11	.1234	-.0786	-.0145	.0156
4.00	-.05	.1562	-.0979	-.0122	.0109	4.00	-.11	.1861	-.1426	-.0156	.0201
6.00	-.05	.2666	-.2201	-.0121	.0119	6.00	-.11	.2913	-.2505	-.0170	.0215
9.00	-.05	.4690	-.4781	-.0105	.0000	9.00	-.13	.4974	-.5101	-.0143	.0064
14.00	-.04	.8623	-1.0176	.0065	-.0652	14.00	.09	.9117	-1.0647	-.0056	.0616
20.00	-.14	1.4130	-1.8052	-.0188	-.0453						
φ = 300°						φ = 300°					
-2.00	-.05	-.0620	.0434	-.0134	.0091	-2.00	-.11	-.0739	.0394	-.0130	.0085
.00	-.06	-.0086	.0383	-.0150	.0125	.00	-.13	.0013	.0031	-.0156	.0113
1.00	-.07	.0531	-.0318	-.0174	.0168	1.00	-.13	.0415	-.0262	-.0167	.0132
2.00	-.07	.1007	-.0749	-.0173	.0166	2.00	-.13	.0899	-.0591	-.0157	.0128
3.00	-.07	.1395	-.0902	-.0190	.0214	3.00	-.15	.1329	-.0885	-.0189	.0170
4.00	-.08	.1806	-.1241	-.0225	.0292	4.00	-.15	.1865	-.1438	-.0194	.0204
6.00	-.06	.2706	-.2107	-.0163	.0176	6.00	-.16	.3020	-.2700	-.0203	.0177
9.00	-.10	.5016	-.5170	-.0221	.0025	9.00	-.27	.5065	-.5252	-.0277	-.0005
14.00	-.30	.8987	-1.0707	-.0648	.0227	14.00	-.75	.8915	-1.0145	-.0766	.0064
20.00	-.79	1.4682	-1.8917	-.2290	.3064						

[redacted]

TABLE III.- ZERO-SPIN TESTS - Continued

(j) 4° fin configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
ϕ = 0°						ϕ = 0°					
-2.00	-.03	-.0973	.0932	-.0073	-.0057	-2.00	-.08	-.1088	.0889	-.0088	-.0035
.00	-.05	-.0258	.0540	-.0117	.0061	.00	-.11	-.0166	.0241	-.0123	.0050
1.00	-.04	.0147	.0202	-.0099	.0008	1.00	-.09	.0224	-.0005	-.0094	-.0025
2.00	-.05	.0535	-.0037	-.0116	.0056	2.00	-.09	.0733	-.0412	-.0098	.0007
3.00	-.06	.1050	-.0452	-.0121	.0071	3.00	-.11	.1150	-.0693	-.0123	.0068
4.00	-.06	.1451	-.0784	-.0126	.0085	4.00	-.10	.1665	-.1147	-.0125	.0087
6.00	-.06	.2709	-.2158	-.0127	.0033	6.00	-.13	.2885	-.2472	-.0150	.0059
9.00	-.08	.4761	-.4792	-.0135	-.0203	9.00	-.24	.5048	-.5231	-.0225	-.0122
14.00	-.25	.8932	-1.0601	-.0513	.0002	14.00	-.68	.9183	-1.0629	-.0716	.0131
20.00	-.60	1.4378	-1.8162	-.1612	.1805						
ϕ = 60°						ϕ = 60°					
-2.00	-.06	-.0927	.0941	-.0132	.0052	-2.00	-.07	-.1067	.0898	-.0072	-.0035
.00	-.05	-.0270	.0632	-.0136	.0088	.00	-.09	-.0179	.0299	-.0101	.0064
1.00	-.05	.0247	.0217	-.0134	.0097	1.00	-.09	.0279	-.0077	-.0110	.0062
2.00	-.06	.0651	-.0119	-.0157	.0139	2.00	-.10	.0723	-.0360	-.0115	.0070
3.00	-.06	.1051	-.0446	-.0162	.0178	3.00	-.10	.1234	-.0807	-.0150	.0184
4.00	-.05	.1441	-.0685	-.0160	.0200	4.00	-.09	.1744	-.1216	-.0128	.0158
6.00	-.06	.2583	-.1966	-.0164	.0227	6.00	-.08	.2852	-.2342	-.0129	.0199
9.00	-.01	.4655	-.4533	-.0048	.0096	9.00	.04	.4868	-.4834	.0048	-.0041
14.00	.25	.8391	-.9492	.0927	-.1820	14.00	.67	.8845	-1.0051	.1172	-.2153
20.00	.84	1.3972	-1.7260	.3266	-.6727						
ϕ = 120°						ϕ = 120°					
-2.00	-.07	-.0916	.0851	-.0145	.0074	-2.00	-.14	-.1035	.0849	-.0179	.0130
.00	-.07	-.0121	.0276	-.0166	.0138	.00	-.14	-.0069	.0069	-.0188	.0176
1.00	-.07	.0260	.0124	-.0171	.0152	1.00	-.14	.0407	-.0257	-.0187	.0173
2.00	-.07	.0727	-.0299	-.0194	.0193	2.00	-.14	.0789	-.0451	-.0171	.0158
3.00	-.08	.1043	-.0361	-.0227	.0280	3.00	-.14	.1253	-.0906	-.0199	.0241
4.00	-.08	.1593	-.1046	-.0256	.0353	4.00	-.15	.1795	-.1360	-.0212	.0281
6.00	-.09	.2664	-.2156	-.0243	.0327	6.00	-.16	.2983	-.2637	-.0212	.0247
9.00	-.07	-.1493	-.3754	-.0195	.0238	9.00	-.12	.5055	-.5284	-.0167	.0178
14.00	-.03	.8722	-1.0334	-.0022	-.0215	14.00	-.01	.9202	-1.0856	.0106	-.0507
20.00	-.01	1.4321	-1.8104	.0125	-.0686						
ϕ = 180°						ϕ = 180°					
-2.00	-.04	-.0909	.0841	-.0092	-.0055	-2.00	-.12	-.1063	.0886	-.0121	-.0004
.00	-.03	-.0252	.0528	-.0078	-.0070	.00	-.10	-.0164	.0237	-.0107	.0000
1.00	-.03	.0152	.0194	-.0078	-.0073	1.00	-.12	.0339	-.0090	-.0124	.0017
2.00	-.05	.0593	-.0042	-.0117	.0019	2.00	-.09	.0760	-.0412	-.0098	.0007
3.00	-.06	.1058	-.0462	-.0122	.0034	3.00	-.11	.1206	-.0695	-.0127	.0058
4.00	-.06	.1585	-.0969	-.0127	.0048	4.00	-.14	.1760	-.1241	-.0161	.0127
6.00	-.07	.2598	-.2002	-.0146	.0023	6.00	-.16	.2896	-.2484	-.0175	.0085
9.00	-.08	.4831	-.4881	-.0181	-.0067	9.00	-.27	.5014	-.5135	-.0293	.0099
14.00	-.25	.8860	-1.0410	-.0543	.0252	14.00	-.71	.9146	-1.0641	-.0803	.0387
20.00	-.54	1.4322	-1.7992	-.1491	.1776						
ϕ = 240°						ϕ = 240°					
-2.00	-.03	-.0923	.0933	-.0080	-.0078	-2.00	-.08	-.1042	.0894	-.0065	-.0092
.00	-.03	-.0202	.0536	-.0078	-.0059	.00	-.08	-.0113	.0240	-.0072	-.0072
1.00	-.04	.0264	.0116	-.0083	-.0044	1.00	-.09	.0340	-.0091	-.0083	-.0060
2.00	-.04	.0718	-.0213	-.0093	-.0013	2.00	-.11	.0788	-.0412	-.0122	.0044
3.00	-.05	.1107	-.0450	-.0109	.0048	3.00	-.10	.1272	-.0820	-.0120	.0078
4.00	-.05	.1647	-.1048	-.0115	.0064	4.00	-.10	.1853	-.1365	-.0125	.0093
6.00	-.04	.2827	-.2233	-.0089	.0040	6.00	-.09	.2910	-.2419	-.0092	.0032
9.00	.01	.4720	-.4556	.0085	-.0262	9.00	.05	.4930	-.4845	.0128	-.0337
14.00	.28	.8595	-.9643	.1159	-.2562	14.00	.71	.8867	-.9868	.1386	-.2896
20.00	.73	1.3760	-1.6746	.2908	-.6145						
ϕ = 300°						ϕ = 300°					
-2.00	-.05	-.0816	.0864	-.0107	.0032	-2.00	-.07	-.0992	.0867	-.0075	-.0015
.00	-.04	-.0081	.0371	-.0094	.0005	.00	-.10	-.0095	.0256	-.0111	.0059
1.00	-.05	.0373	.0042	-.0117	.0058	1.00	-.09	.0394	-.0162	-.0107	.0047
2.00	-.06	.0704	-.0118	-.0134	.0082	2.00	-.11	.0841	-.0446	-.0127	.0085
3.00	-.06	.1103	-.0444	-.0144	.0138	3.00	-.10	.1321	-.0813	-.0140	.0131
4.00	-.05	.1632	-.0951	-.0137	.0131	4.00	-.11	.1786	-.1269	-.0156	.0193
6.00	-.05	.2888	-.2317	-.0159	.0184	6.00	-.12	.3006	-.2588	-.0153	.0168
9.00	-.03	.4867	-.4839	-.0067	-.0068	9.00	-.06	.5118	-.5259	-.0048	-.0091
14.00	.02	.9032	-1.0558	.0294	-.1098	14.00	-.07	.9180	-1.0624	.0179	-.1072
20.00	.19	1.4168	-1.7706	.1140	-.3192						

[redacted]

TABLE III.- ZERO-SPIN TESTS - Continued [redacted]

(c) Regular shroud configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
φ = 0°						φ = 0°					
-2.00	-.05	-.1183	.1504	-.0082	-.0118	-2.00	-.08	-.1038	.0971	-.0049	-.0144
.00	-.03	-.0573	.1115	-.0050	-.0164	.00	-.08	-.0161	.0249	-.0068	-.0106
1.00	-.03	.0031	.0357	-.0038	-.0177	1.00	-.09	.0238	-.0090	-.0076	-.0100
2.00	-.04	.0373	.0070	-.0072	-.0096	2.00	-.09	.0631	-.0383	-.0070	-.0121
3.00	-.04	.0767	-.0222	-.0084	-.0076	3.00	-.09	.1049	-.0675	-.0069	-.0124
4.00	-.04	.1151	-.0424	-.0077	-.0097	4.00	-.10	.1435	-.0919	-.0089	-.0084
6.00	-.05	.1954	-.1105	-.0088	-.0092	6.00	-.11	.2427	-.1705	-.0095	-.0128
9.00	-.10	.3512	-.2476	-.0201	.0053	9.00	-.24	.3874	-.2841	-.0249	.0072
14.00	-.33	.6063	-.3986	-.0966	.1461	14.00	-.82	.6468	-.4170	-.1223	.1850
20.00	-.81	.9528	-.6409	-.2712	.4982						
φ = 60°						φ = 60°					
-2.00	-.02	-.0958	.1246	-.0032	-.0140	-2.00	-.06	-.0940	.0973	-.0030	-.0162
.00	-.04	-.0270	.0666	-.0084	-.0020	.00	-.06	-.0119	.0301	-.0043	-.0123
1.00	-.03	.0253	.0181	-.0059	-.0070	1.00	-.05	.0303	-.0033	-.0026	-.0140
2.00	-.05	.0659	-.0201	-.0100	.0029	2.00	-.07	.0682	-.0229	-.0069	-.0041
3.00	-.05	.0993	-.0400	-.0099	.0026	3.00	-.08	.1110	-.0610	-.0080	-.0008
4.00	-.05	.1384	-.0683	-.0102	.0078	4.00	-.10	.1527	-.0897	-.0108	.0066
6.00	-.05	.2373	-.1637	-.0147	.0216	6.00	-.10	.2459	-.1662	-.0123	.0125
9.00	-.02	.3903	-.2941	-.0130	.0412	9.00	.00	.3979	-.2843	-.0059	.0300
14.00	.11	.6280	-.4146	.0203	.0160	14.00	.43	.6428	-.3944	.0436	-.0067
20.00	.45	.9560	-.6025	.1186	-.1321						
φ = 120°						φ = 120°					
-2.00	-.04	-.0891	.1075	-.0106	.0094	-2.00	-.07	-.0962	.1049	-.0070	.0033
.00	-.04	-.0093	.0405	-.0127	.0173	.00	-.09	-.0075	.0244	-.0129	.0196
1.00	-.05	.0176	.0302	-.0150	.0217	1.00	-.09	.0285	.0003	-.0143	.0238
2.00	-.05	.0492	.0205	-.0172	.0298	2.00	-.08	.0774	-.0468	-.0141	.0266
3.00	-.05	.1046	-.0550	-.0189	.0350	3.00	-.09	.1096	-.0613	-.0163	.0334
4.00	-.06	.1381	-.0754	-.0195	.0341	4.00	-.10	.1581	-.1041	-.0194	.0417
6.00	-.06	.2370	-.1712	-.0187	.0342	6.00	-.11	.2482	-.1721	-.0210	.0445
9.00	-.08	.3773	-.2691	-.0267	.0508	9.00	-.15	.3982	-.2926	-.0286	.0614
14.00	-.15	.6245	-.4066	-.0586	.1210	14.00	-.36	.6576	-.4311	-.0656	.1371
20.00	-.32	.9934	-.6973	-.1185	.2444						
φ = 180°						φ = 180°					
-2.00	-.05	-.1006	.1104	-.0193	.0364	-2.00	-.10	-.0981	.0935	-.0185	.0359
.00	-.06	-.0355	.0804	-.0208	.0412	.00	-.11	-.0135	.0262	-.0198	.0398
1.00	-.06	.0264	-.0053	-.0214	.0416	1.00	-.10	.0297	-.0126	-.0183	.0351
2.00	-.06	.0532	-.0153	-.0225	.0449	2.00	-.11	.0788	-.0601	-.0197	.0393
3.00	-.07	.1064	-.0727	-.0266	.0535	3.00	-.13	.1175	-.0846	-.0226	.0448
4.00	-.06	.1386	-.0833	-.0217	.0438	4.00	-.13	.1591	-.1135	-.0239	.0489
6.00	-.07	.2370	-.1712	-.0246	.0460	6.00	-.17	.2521	-.1859	-.0305	.0625
9.00	-.11	.3613	-.2535	-.0332	.0490	9.00	-.27	.3954	-.2790	-.0403	.0622
14.00	-.34	.6301	-.4179	-.1026	.1618	14.00	-.85	.6480	-.4023	-.1297	.2069
20.00	-.82	.9621	-.6224	-.2762	.5159						
φ = 240°						φ = 240°					
-2.00	-.05	-.0856	.0796	-.0101	.0079	-2.00	-.08	-.0922	.0693	-.0114	.0169
.00	-.05	-.0192	.0400	-.0129	.0137	.00	-.10	.0013	-.0076	-.0159	.0275
1.00	-.06	.0215	.0014	-.0141	.0159	1.00	-.08	.0305	-.0177	-.0146	.0261
2.00	-.05	.0608	-.0274	-.0121	.0139	2.00	-.11	.0767	-.0609	-.0181	.0328
3.00	-.05	.1003	-.0566	-.0126	.0154	3.00	-.09	.1253	-.1038	-.0152	.0288
4.00	-.05	.1547	-.1232	-.0143	.0194	4.00	-.09	.1637	-.1277	-.0174	.0356
6.00	-.05	.2947	-.2655	-.0162	.0308	6.00	-.08	.2627	-.2089	-.0165	.0374
9.00	-.01	.3651	-.2649	-.0089	.0311	9.00	.03	.4020	-.3006	-.0061	.0412
14.00	.14	.6068	-.3915	.0235	.0195	14.00	.52	.6366	-.3787	.0479	.0130
20.00	.53	.9646	-.6560	.1479	-.1900						
φ = 300°						φ = 300°					
-2.00	-.05	-.0841	.0768	-.0105	-.0020	-2.00	-.09	-.0877	.0690	-.0070	-.0106
.00	-.04	-.0242	.0470	-.0091	-.0037	.00	-.13	-.0029	-.0023	-.0139	.0065
1.00	-.06	.0226	-.0009	-.0132	.0049	1.00	-.12	.0463	-.0535	-.0139	.0115
2.00	-.06	.0619	-.0296	-.0148	.0099	2.00	-.11	.0880	-.0823	-.0140	.0133
3.00	-.06	.1087	-.0775	-.0141	.0091	3.00	-.12	.1331	-.1201	-.0156	.0195
4.00	-.06	.1430	-.1064	-.0147	.0107	4.00	-.13	.1724	-.1492	-.0185	.0251
6.00	-.07	.2346	-.1840	-.0163	.0130	6.00	-.13	.2685	-.2263	-.0195	.0274
9.00	-.09	.3830	-.3092	-.0237	.0303	9.00	-.19	.4110	-.3283	-.0283	.0452
14.00	-.18	.6229	-.4359	-.0607	.1154	14.00	-.42	.6622	-.4545	-.0760	.1527
20.00	-.36	.9877	-.7051	-.1326	.2722						

[redacted]

TABLE III.- ZERO-SPIN TESTS - Concluded

(d) Half-barrel shroud configuration

V = 400 ft/sec						V = 600 ft/sec					
α, deg	ψ, deg	C_N	C_m	C_Y	C_n	α, deg	ψ, deg	C_N	C_m	C_Y	C_n
$\phi = 0^\circ$						$\phi = 0^\circ$					
-2.00	-.06	-.0975	.0921	-.0142	.0157	-2.00	-.10	-.1043	.0855	-.0152	.0219
.00	-.06	-.0095	.0025	-.0140	.0166	.00	-.10	.0012	-.0261	-.0165	.0258
1.00	-.07	.0233	-.0149	-.0198	.0288	1.00	-.11	.0371	-.0480	-.0172	.0281
2.00	-.07	.0659	-.0690	-.0198	.0288	2.00	-.12	.1176	-.1419	-.0178	.0296
3.00	-.06	.1110	-.1042	-.0184	.0286	3.00	-.11	.1296	-.1368	-.0179	.0315
4.00	-.07	.1602	-.1678	-.0214	.0324	4.00	-.09	.1852	-.1948	-.0143	.0252
6.00	-.06	.2378	-.2197	-.0199	.0357	6.00	-.10	.2783	-.2730	-.0203	.0455
9.00	-.01	.4032	-.3679	-.0107	.0362	9.00	.00	.4281	-.3840	-.0105	.0460
14.00	.19	.7413	-.6682	.0533	-.0670	14.00	.34	.7103	-.5919	.0340	.0029
20.00	.62	1.0452	-.8762	.2109	-.3808						
$\phi = 60^\circ$						$\phi = 60^\circ$					
-2.00	-.04	-.0910	.0897	-.0086	-.0055	-2.00	-.10	-.0957	.0870	-.0103	-.0006
.00	-.04	.0032	-.0091	-.0091	-.0041	.00	-.10	-.0028	-.0024	-.0102	-.0011
1.00	-.04	.0298	-.0175	-.0089	-.0032	1.00	-.08	.0439	-.0513	-.0086	-.0025
2.00	-.04	.0813	-.0620	-.0088	-.0023	2.00	-.10	.0907	-.1002	-.0100	.0016
3.00	-.05	.1177	-.1071	-.0112	.0022	3.00	-.11	.1359	-.1357	-.0128	.0076
4.00	-.05	.1694	-.1517	-.0117	.0037	4.00	-.12	.2248	-.2753	-.0129	.0071
6.00	-.07	.2688	-.2506	-.0163	.0122	6.00	-.11	.2818	-.2608	-.0126	.0061
9.00	-.07	.4094	-.3490	-.0166	.0117	9.00	-.18	.6270	-.8569	-.0219	.0178
14.00	-.15	.7272	-.6363	-.0416	.0580	14.00	-.34	.7249	-.6147	-.0487	.0663
20.00	-.33	1.0898	-.9203	-.1111	.1993						
$\phi = 120^\circ$						$\phi = 120^\circ$					
-2.00	-.03	-.1001	.1248	-.0011	-.0260	-2.00	-.07	-.0939	.0953	-.0037	-.0177
.00	-.03	-.0248	.0536	-.0026	-.0499	.00	-.05	-.0054	.0197	-.0011	-.0209
1.00	-.02	.0415	-.0271	-.0019	-.0193	1.00	-.05	.0418	-.0298	-.0014	-.0214
2.00	-.03	.0748	-.0452	-.0031	-.0185	2.00	-.06	.0944	-.0834	-.0033	-.0168
3.00	-.02	.1222	-.0987	-.0006	-.0207	3.00	-.05	.1414	-.1326	-.0003	-.0220
4.00	-.02	.1616	-.1255	-.0017	-.0188	4.00	-.06	.1862	-.1637	-.0032	-.0166
6.00	-.02	.3176	-.3061	.0002	-.0232	6.00	-.08	.2772	-.2391	-.0062	-.0088
9.00	-.05	.4044	-.3347	-.0094	-.0160	9.00	-.16	.4344	-.3628	-.0164	-.0030
14.00	-.26	.6834	-.5439	-.0722	.0898	14.00	-.74	.7323	-.5972	-.1034	.1335
20.00	-.73	1.0874	-.9165	-.2429	.4356						
$\phi = 180^\circ$						$\phi = 180^\circ$					
-2.00	-.04	-.1279	.1802	-.0067	-.0098	-2.00	-.06	-.1185	.1462	-.0034	-.0129
.00	-.02	-.0326	.0725	-.0007	-.0202	.00	-.06	-.0220	.0478	-.0059	-.0073
1.00	-.03	-.0061	.0642	-.0071	-.0063	1.00	-.05	.0230	.0127	-.0049	-.0072
2.00	-.03	.0479	.0012	-.0070	-.0064	2.00	-.06	.0701	-.0367	-.0066	-.0040
3.00	-.03	.0871	-.0254	-.0051	-.0095	3.00	-.06	.1133	-.0768	-.0053	-.0058
4.00	-.03	.1345	-.0788	-.0074	-.0026	4.00	-.06	.1621	-.1211	-.0064	-.0020
6.00	-.04	.2323	-.1676	-.0083	.0028	6.00	-.05	.2656	-.2181	-.0069	.0050
9.00	.01	.3918	-.3072	.0026	-.0019	9.00	.07	.4089	-.3157	.0071	-.0025
14.00	.21	.6616	-.5093	.0670	-.1105	14.00	.61	.7005	-.5348	.0961	-.1570
20.00	.59	1.0403	-.8251	.2034	-.3812						
$\phi = 240^\circ$						$\phi = 240^\circ$					
-2.00	-.07	-.1282	.1741	-.0210	.0313	-2.00	-.11	-.1230	.1500	-.0178	.0320
.00	-.07	-.0471	.0945	-.0225	.0386	.00	-.12	-.0236	.0474	-.0212	.0396
1.00	-.06	.0079	.0224	-.0190	.0318	1.00	-.10	.0265	-.0066	-.0174	.0312
2.00	-.07	.0407	.0050	-.0236	.0417	2.00	-.11	.0722	-.0465	-.0181	.0335
3.00	-.06	.0811	-.0309	-.0206	.0353	3.00	-.12	.1118	-.0776	-.0210	.0389
4.00	-.08	.1274	-.0754	-.0240	.0430	4.00	-.11	.1641	-.1307	-.0203	.0400
6.00	-.08	.2194	-.1560	-.0239	.0425	6.00	-.13	.2679	-.2251	-.0226	.0415
9.00	-.09	.3805	-.2991	-.0301	.0546	9.00	-.17	.4141	-.3322	-.0280	.0496
14.00	-.15	.6464	-.4972	-.0482	.0810	14.00	-.40	.7035	-.5575	-.0647	.1073
20.00	-.40	1.0514	-.8802	-.1383	.2625						
$\phi = 300^\circ$						$\phi = 300^\circ$					
-2.00	-.06	-.0906	.1126	-.0209	.0364	-2.00	-.11	-.0964	.0970	-.0212	.0432
.00	-.06	-.0292	.0691	-.0218	.0432	.00	-.12	-.0107	.0215	-.0225	.0471
1.00	-.06	.0388	-.0218	-.0236	.0446	1.00	-.13	.0352	-.0187	-.0227	.0470
2.00	-.06	.0716	-.0391	-.0217	.0428	2.00	-.12	.0852	-.0723	-.0227	.0475
3.00	-.08	.1183	-.0842	-.0258	.0499	3.00	-.11	.1343	-.1207	-.0222	.0495
4.00	-.07	.1659	-.1379	-.0275	.0550	4.00	-.10	.1826	-.1609	-.0204	.0458
6.00	-.06	.2563	-.2013	-.0233	.0433	6.00	-.15	.2835	-.2510	-.0277	.0559
9.00	-.12	.4272	-.3667	-.0366	.0538	9.00	-.25	.4276	-.3488	-.0373	.0542
14.00	-.33	.7074	-.5849	-.1030	.1664	14.00	-.92	.7271	-.5860	-.1681	.3358
20.00	-.80	1.0842	-.9034	-.2760	.5154						

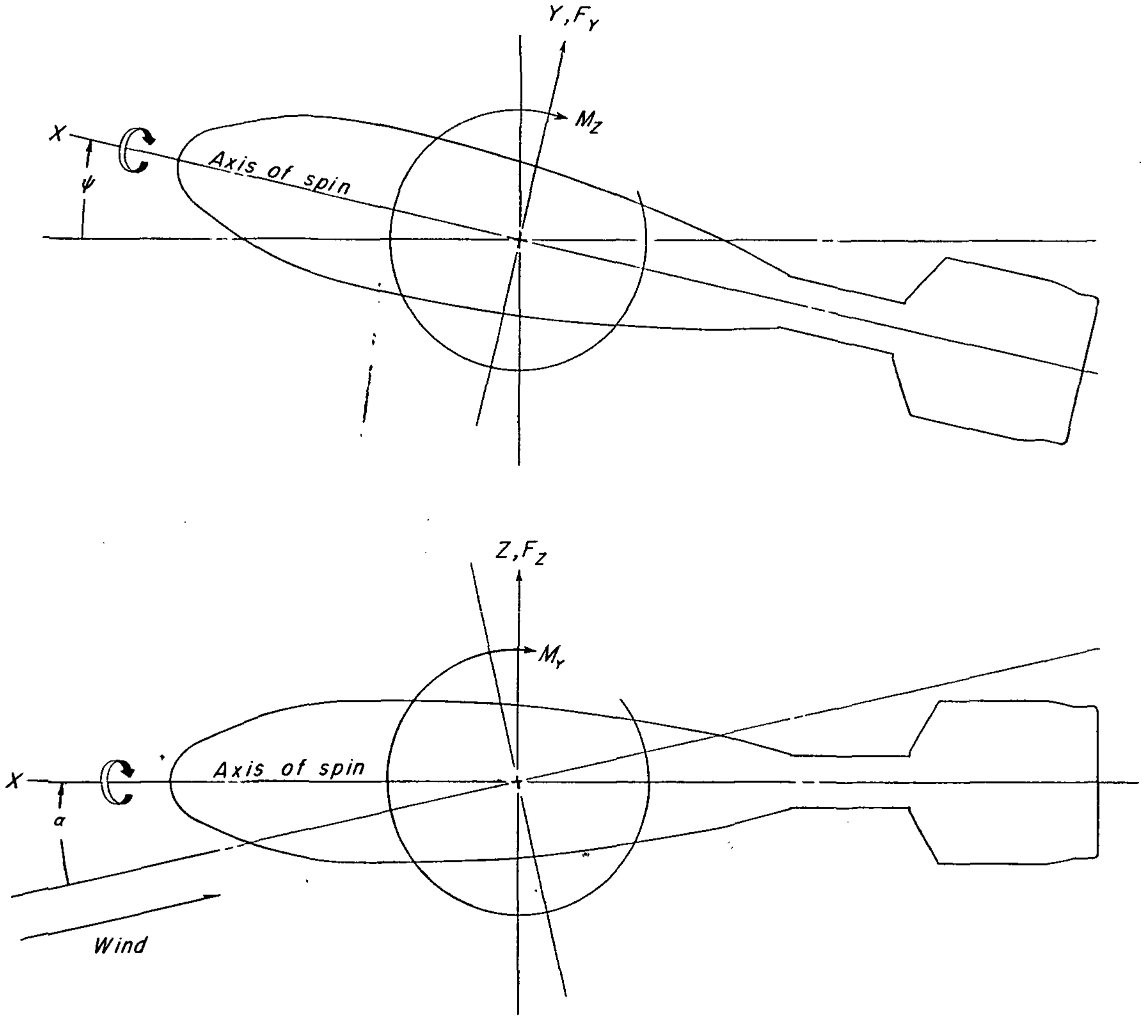


Figure 1.- System of axes. Arrows indicate positive directions of forces, moments, and angles.

[redacted]

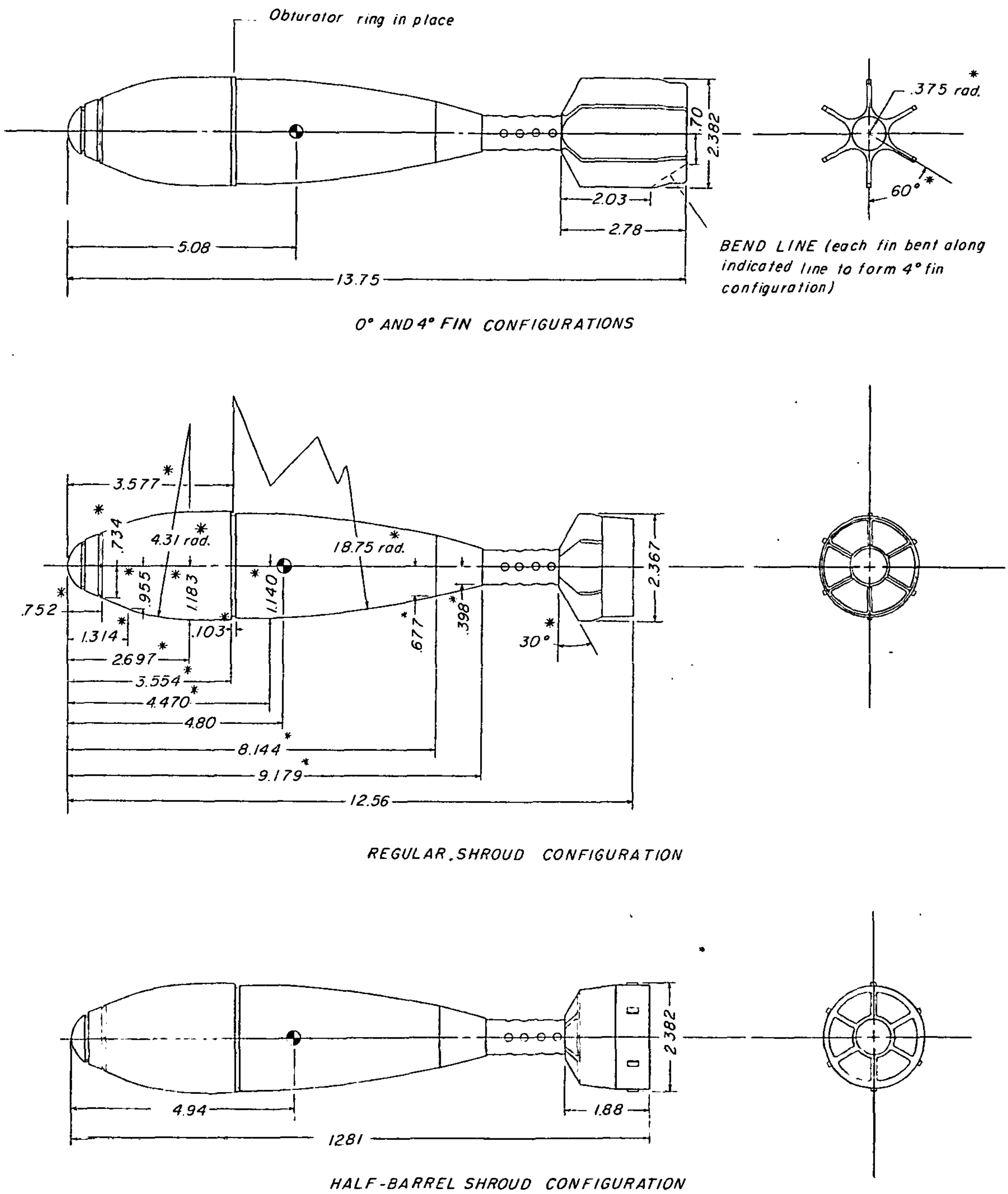
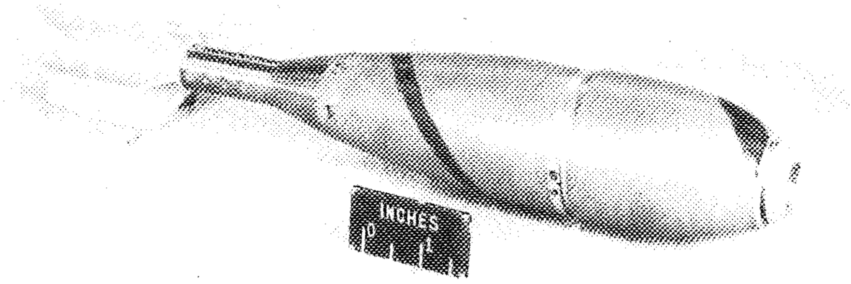
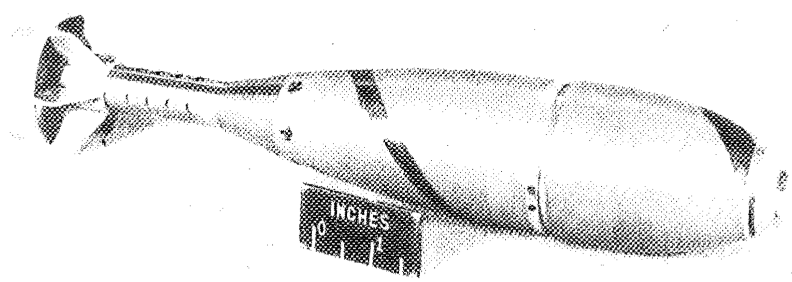


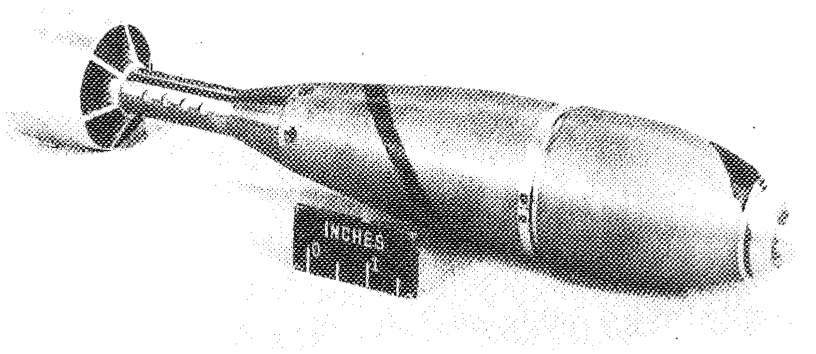
Figure 2.- Details of models. Starred dimensions are common to all models. All dimensions are in inches unless otherwise indicated.



0° fin configuration L-94070



Regular shroud configuration L-94069



Half-barrel shroud configuration L-94068

Figure 3.- Models used in the investigation.

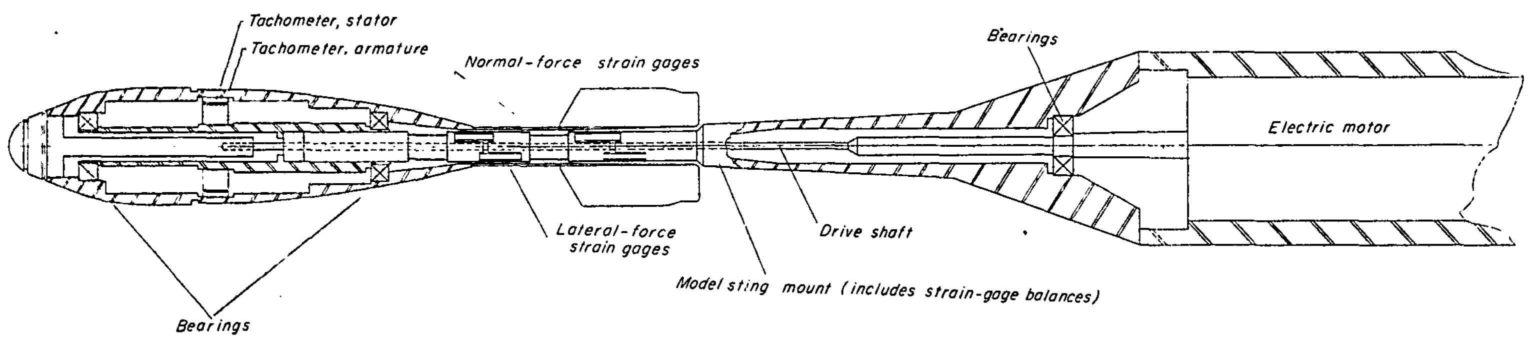


Figure 4.- Schematic drawing of model mount and drive system.

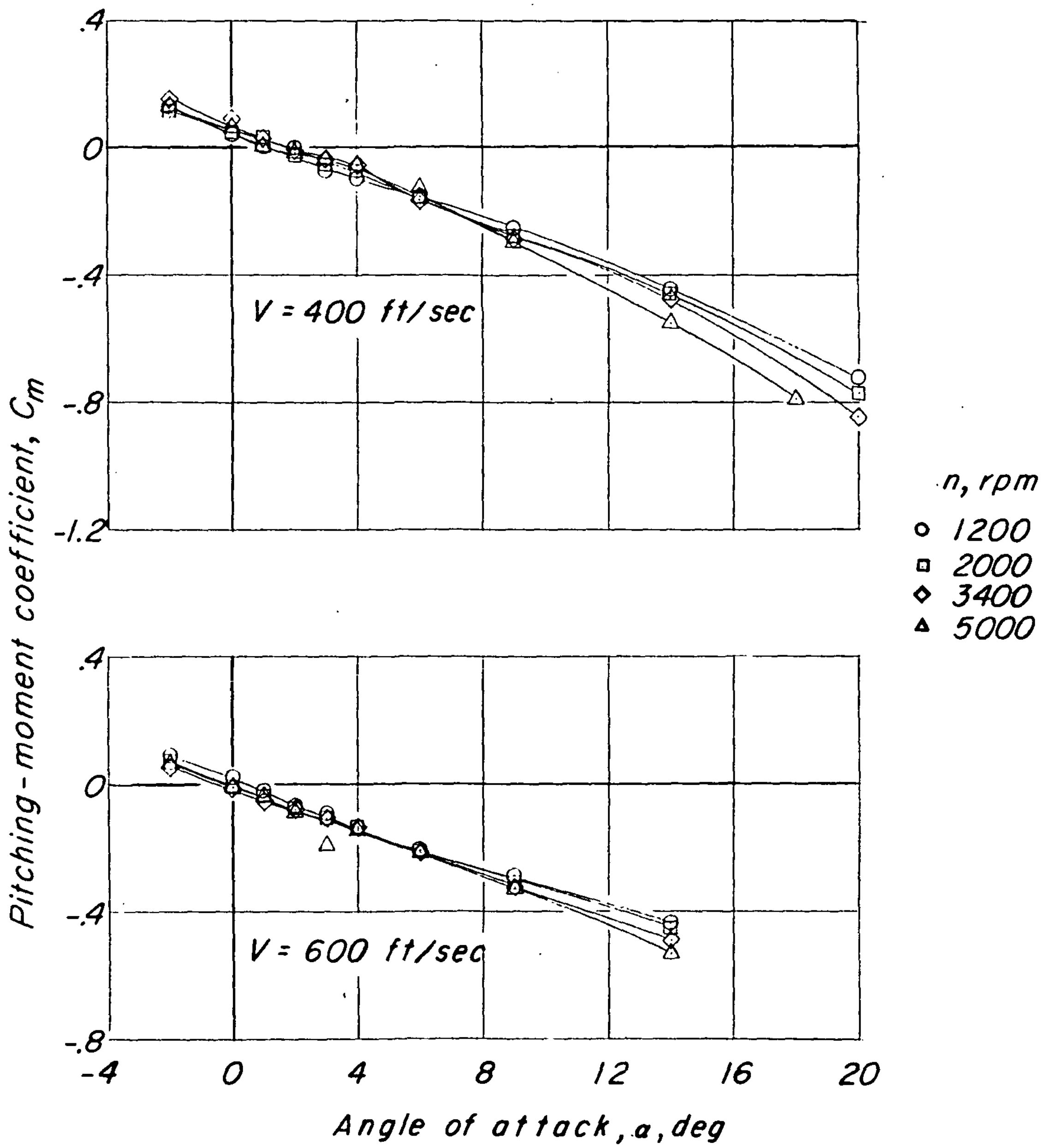


Figure 5.- Effect of speed of rotation on pitching moment. Regular shroud configuration.

[redacted]

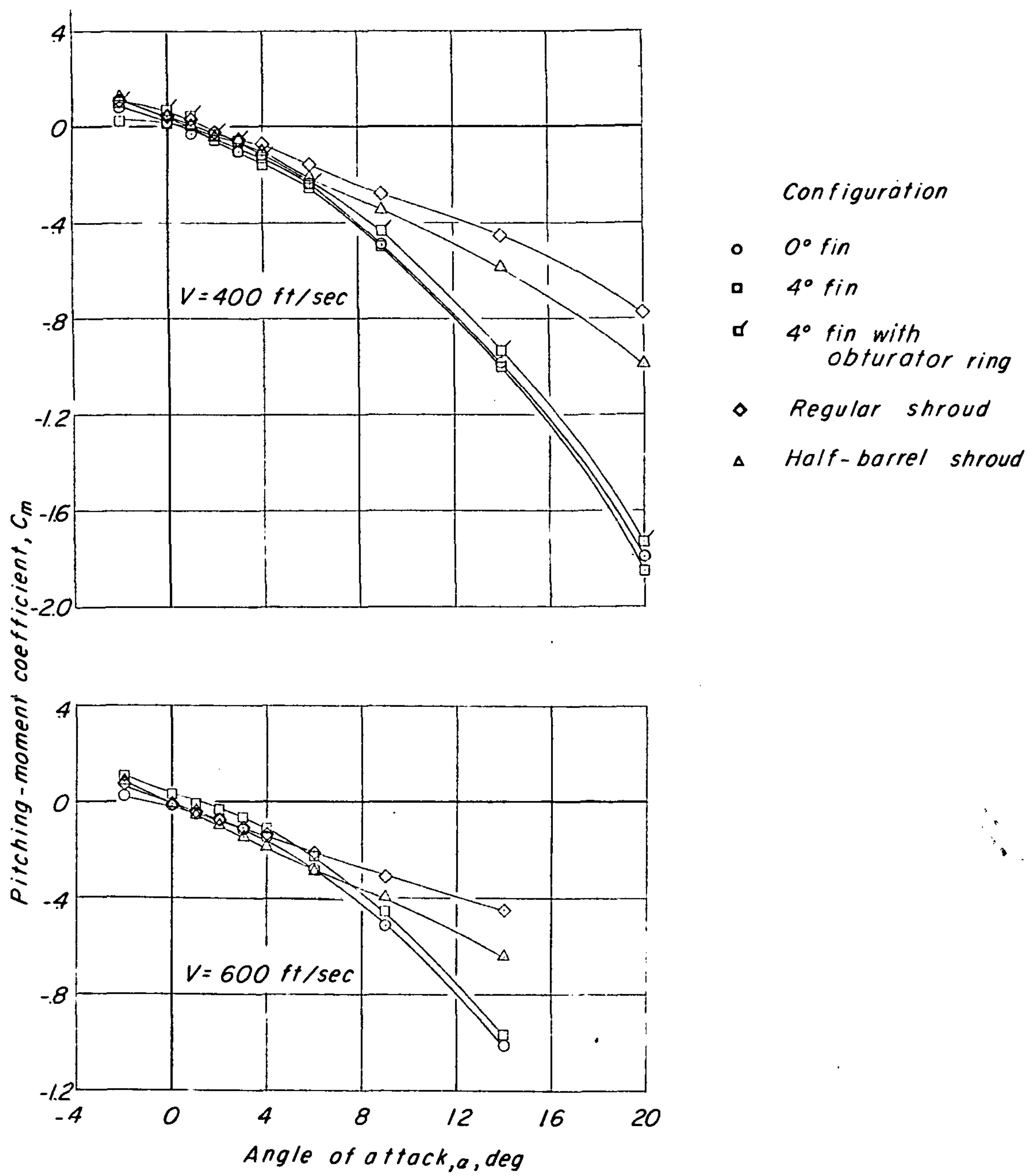
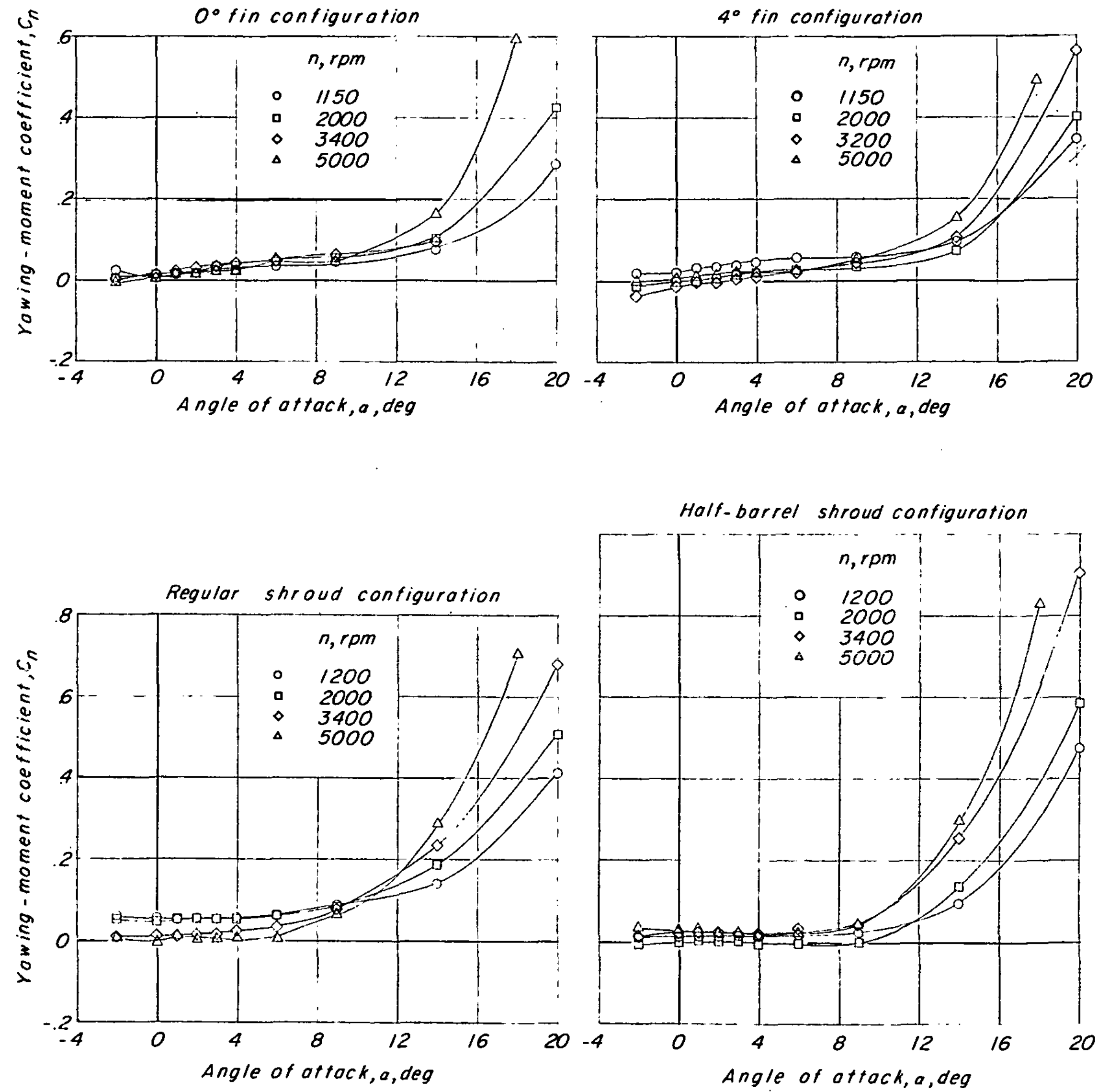


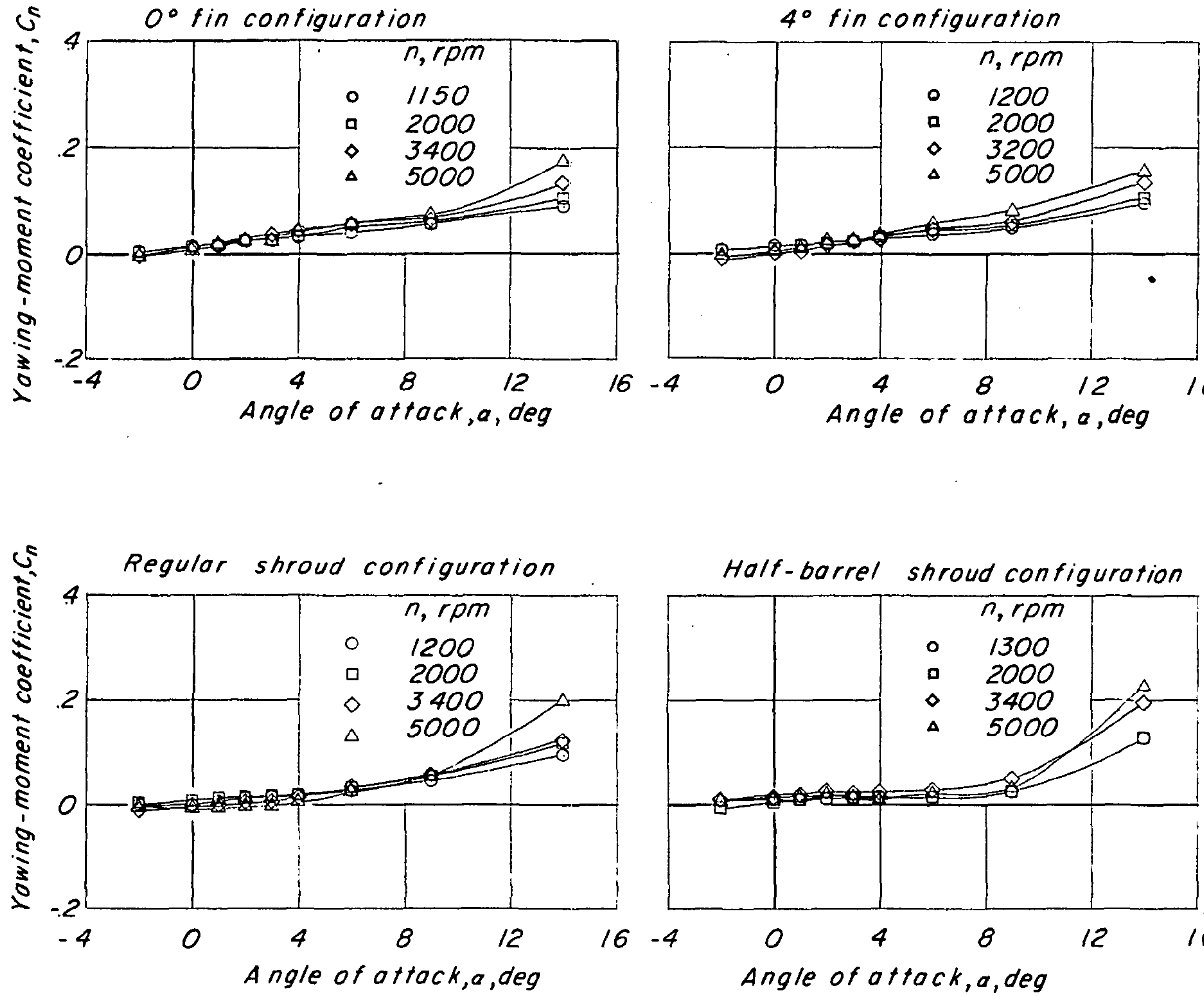
Figure 6.- Effect of model configuration on the variation of pitching-moment coefficient with angle of attack. 2,000 rpm.

[redacted]



(a) V = 400 feet per second.

Figure 7.- Effect of speed of rotation on the variation of the yawing-moment coefficient with angle of attack.



(b) V = 600 feet per second.

Figure 7.- Concluded.

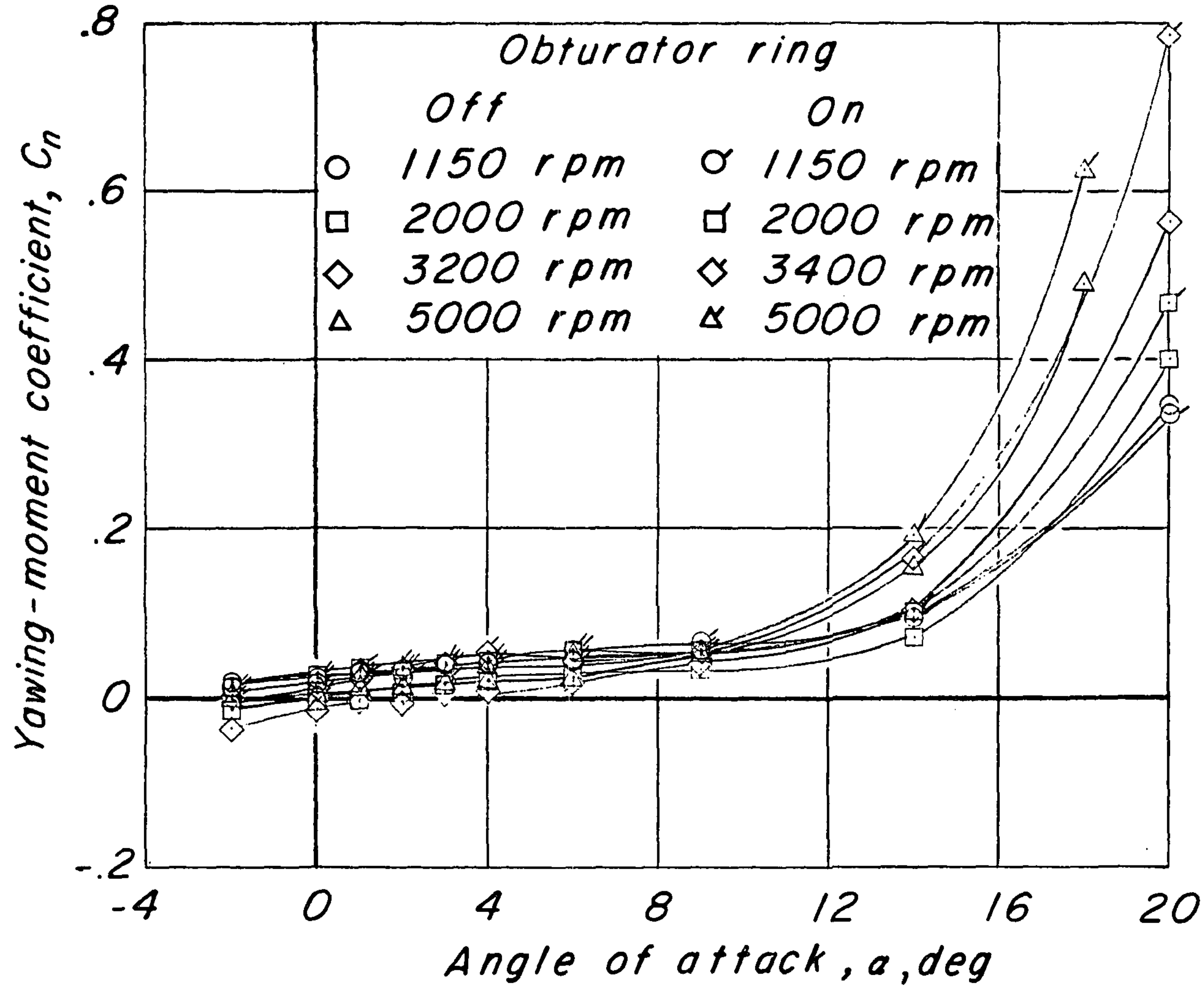


Figure 8.- Effect of the addition of the obturator ring to the 4° fin configuration.

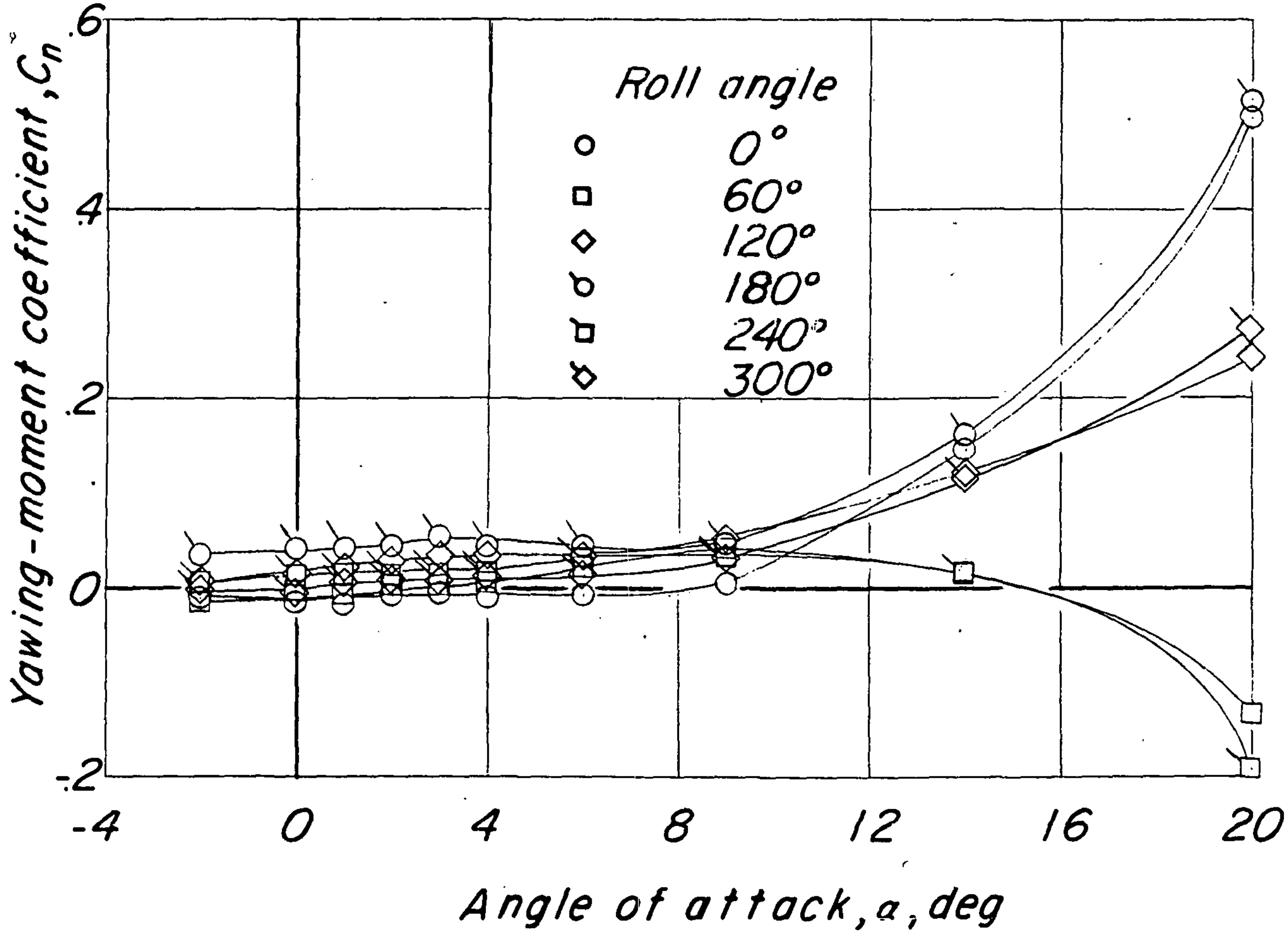


Figure 9.- Variation of yawing-moment coefficient with angle of attack for the regular shroud configuration. Model 1 locked at each angle.

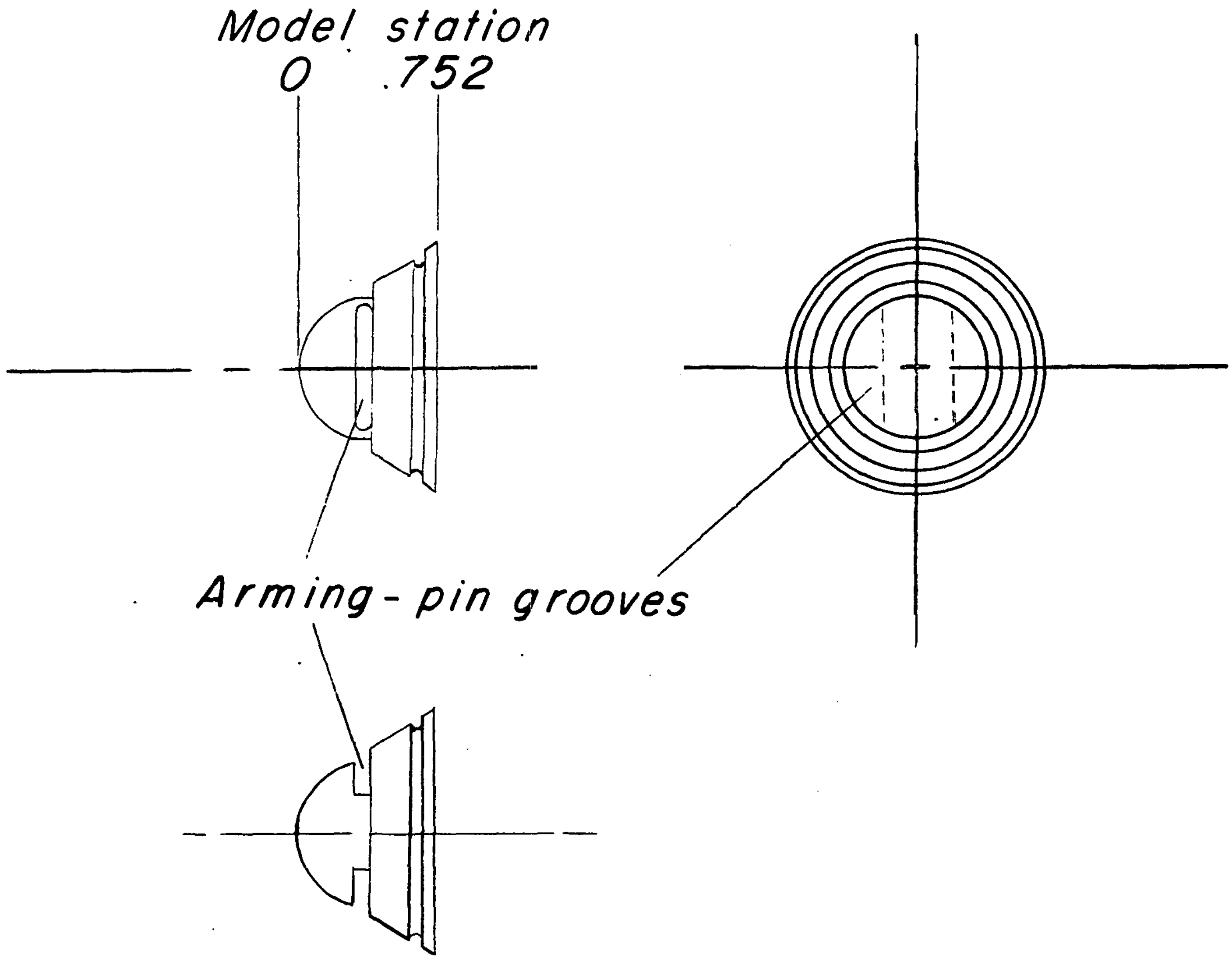


Figure 10.- Sketch of model nose showing arming-pin grooves.

 [redacted]

WIND-TUNNEL INVESTIGATION OF THE EFFECT OF SPIN ON THE AERODYNAMIC CHARACTERISTICS OF A 60-MILLIMETER T-24 MORTAR SHELL WITH SEVERAL TAIL-FIN CONFIGURATIONS

By William B. Kemp, Jr., and William C. Hayes, Jr.

ABSTRACT

An investigation has been made in the Langley high-speed 7- by 10-foot tunnel to determine the effect of spin on the aerodynamic characteristics of a 60-millimeter T-24 mortar shell fitted with several different tail-fin configurations. Tests were made at airspeeds of 400 and 600 feet per second, at speeds of rotation from 0 to 5,000 rpm, and through the angle-of-attack range from -2° to 20°.

INDEX HEADINGS

Tail-Body Combinations - Missiles	1.7.2.1.2
Missiles, Specific Types	1.7.2.2
Stability, Longitudinal - Static	1.8.1.1.1
Stability, Lateral and Directional - Dynamic	1.8.1.2.2

[redacted]

[redacted]

[redacted]

[redacted]